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ABSTRACT

This report describes a curriculum development program designed to address three problems associated with computer use in the schools: underutilization of the computer capabilities by overemphasis on basic skills instruction; stratified access to computers, or inequitable access based on race, sex, or income; and emphasis on teaching computer programming when the skills needed for the workplace are much more diverse. This project involved the systematic introduction of computer curricula in language arts and mathematics to students in grades 2-6. One classroom was part of a designated bilingual program, two others had a number of students who spoke Spanish as a first language, and one was designated as a Chapter 1 classroom. The report is presented in nine chapters: (1) "Introduction" (Hugh Mehan); (2) "The Classrooms" (Marcia Boruta, Ann Marie Newcombe, Marti tum Suden, and Christina Drale); (3) "Microcomputers and Classroom Organization: Some Mutual Influences" (Hugh Mehan); (4) "Some Cognitive and Social Benefits of Peer Interaction on Computers" (Hugh Mehan, Nick Maroules, and Christina Drale); (5) "A Holistic Approach to Computer Literacy" (Hugh Mehan, Margaret M. Riel, Marcia Boruta, Christina Drale, Nick Maroules, and Kim Whooley); (6) "Functional Learning Environments for Writing" (Margaret M. Riel); (7) "Computer Activities in a Bilingual Setting" (Luis C. Moll and Ann Marie Newcombe); (8) "Teaching Problem Solving Strategies" (Marti tum Suden and Robert Rowe); and (9) "Summary and Conclusions" (Hugh Mehan, Luis Moll, and Margaret M. Riel). The text is supplemented by 25 tables, 151 figures, and 103 references. Two appendices contain guidelines for selecting prompts and rubrics for use in teaching writing and a functional computer literacy test. (EW)

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COMPUTERS IN CLASSROOMS:

A QUASI-EXPERIMENT IN GUIDED CHANGE

GRANT # NIE 6-83-0027

FINAL REPORT

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CHAPTER 1:

INTRODUCTION

Hugh Mehan

Prevailing Uses of Microcomputers in Schools

Recent national surveys of computer use (CSOS, 1982; Tucker, 1983) and surveys conducted in the San Diego area (Miller, 1983, Boruta et al., 1983; Cohen, 1984) have shown that microcomputers are used primarily to teach programming and to provide drill and practice in basic skills. The current state of computer use in schools presents educators and the society at large with a number of problems. First, the use of microcomputers for drill and practice does not fully utilize the capabilities of this technology for education. Second, women, lower income and ethnic minority students do not have the same access to educational technology as do their male, middle income, and majority counterparts. Third, treating computer programming as the end point of a computer curriculum overlooks the needs of society and the work place.

Basic Skills Instruction

The most prevalent instructional application of computer use today is for basic skills instruction. Basic skills instruction usually means computer Aided Instruction" (CAI) (see Atkinson, 1972; Suppes, 1980). The extent to which CAI software is used is indicated by a recent study of 2000 computer using teachers who were asked: "What are your favorite educational software programs?" (Patterson, 1983). Of the 93 programs identified, 27 were for professional and administrative purposes, and 66 were for instructional purposes. Nearly all of the instructional programs were devoted to drill and practice or reinforcement of existing skills in math, social science and English. They were not used to generate new instructional activities.

When computers are used for basic skills instruction, students are commonly given drill and practice which reinforces instruction on material already presented in their classrooms. The material to be learned and the sequence in which it is learned is rigidly fixed by the teacher and the software. The material to be presented to students is restricted to a specific problem domain, offers a narrow range of response options and is presented to the students in very small steps (Amarel, 1983; Riel, 1983). When a correct answer is selected, the students are rewarded with a visual or musical display, often unrelated to lesson materials.

Programming

The second most common instructional application of computer use today is for "computer literacy." Computer literacy has come to mean teaching students to program computers, primarily in the BASIC language.

Computer programming is emphasized in computer literacy curricula because programming enables students to gain control of the machine (Papert, 1980). Another reason given for emphasizing programming is that it strengthens students' higher level reasoning skills. While there is no reason to argue against the first premise, there is little evidence to support the second (Pea and Kurland, 1984; see Chapter 8 of this report). Even if there were considerable evidence to suggest that learning to program enhances higher order thinking, it may be short sighted to teach all students to program in BASIC.

BASIC is a general purpose programming language. While its linear structure makes it relatively easy to learn initial commands and statements, this same structure makes it difficult for beginning students to create any but the most rudimentary programs. BASIC is also limited in that it does not easily allow for hierarchically arranged programming procedures in the more modern languages, PASCAL and LOGO. Whether working in BASIC, PASCAL or LOGO, however, students receive only a limited sense of the computer's power. With special purpose languages such as Interactive Texts or spread sheets, students develop a richer sense of how to structure problems effectively and to approach problems in a disciplined way, (i.e., two of the general or "metacognitive" skills that some cognitive scientists believe can be widely applied to solving problems).

Problems With Current Uses of Microcomputers

We see a number of problems with the current uses of microcomputers in schools. The present pattern does not capitalize on the full capabilities of the technology. Furthermore, prevailing educational uses stratify access to microcomputers along social class, gender, and ethnic lines. Of equal importance, they do not match the ways in which computers are used in the work place.

Underutilization of the Computer's Capabilities

The fast pace and packaged format of CAI drill and practice software provides little opportunity to deliberate, to reconsider, or to challenge the prespecified answers. These programs assume limited knowledge on the part of the students and aim to strengthen and broaden that knowledge by repeated exposure to a similar class of exercises (Amarael, 1983). Little attempt is made to extend or apply existing knowledge.

While there is some evidence to suggest that microcompuers can deliver basic skills instruction better than conventional techniques (Kulik et al., 1983), critics of such studies (Tucker, 1983) point to the methodological problems and omissions of cost comparisons. Typically, the effectiveness studies compare the effects of recently introduced CAI programs to conventional workbook activities. These comparisons may provide a statistically significant advantage for CAI. So far, effectiveness studies have not compared CAI to methods such as cross-age tutoring, which have also been shown to improve students' learning. The utility of CAI for improving students' basic skills diminishes when the high cost of computers is taken into consideration (Tucker, 1983).

Furthermore, when the novelty of working with computers wears off, CAI workbook pages do not have the motivating effect required to sustain students' interest (Malone, 1981). In addition, the current readability and graphic quality of electronic worksheets is poorer than printed workbooks, which makes their use as an alternative medium of communication between teacher and student questionable.

Equitable Access to Educational Technology

While the most prevalent educational uses of microcomputers are basic skills instruction and computer programming, access to computers and their uses is differentially distributed. Ethnic minority and low income students receive a different kind of instruction on computers than their middle income and ethnic majority contemporaries. While middle class students, especially those who are in advanced programs (e.g., Gifted and Talented Education) receive instruction which encourages learner initiative (programming and problem solving), low income and ethnic minority students receive CAI instruction which maintains the control of learning within the program (CSOS, 1983; Boruta et al., 1983).

Males and females also have differential access to computers, (CSOS, 1983; Boruta et al., 1983), especially in secondary schools (Sheingold et al., 1983). In elementary schools that have established central computer labs, boys and girls have equal access. However, this equality is not duplicated during voluntary times on computers (recess, lunch, after school clubs). More boys than girls use computers in their spare time. The equality of access reported in elementary schools disappears in secondary schools. When students are divided into curricular tracks, (college preparatory, vocational and general education), a stratification of males and females becomes apparent. Males gain greater access to computer and math labs than females.

This tracking of students by gender and socioeconomic background through different curricular tracks stratifies students' access to information technology. Differential access represents one of the ways in which the microcomputer can become a tool which contributes further to the stratification that already exists in our society. If only a few people learn to control computers, and most can only react passively to them, then we will have a system of stratification based on access to information technology (Schiller, 1981) that will make the ones based on economic capital (Marx, 1964) and cultural capital (Bourdieu and Passeron, 1977; Collins, 1980) pale by comparison.

The Needs of Society and the Work Place

The computer is a general purpose machine. It processes information that can be used for a wide variety of instructional and administrative purposes. These wide-ranging capabilities of the computer, coupled with parental pressure and pressure from business and industry, are the main reasons computers are having such a dominant impact on education. However, knowing that the computer *can* be used for almost any purpose does not tell schools what it *should* be used for. In fact, it is its flexibility that is so dazzling. Since the machine can be programmed to do many things, we must search for the constraints which tell us which computer applications make sense and which do not. We must also take into consideration the cost of applications in dollars, time and human costs.

As schools and universities organize educational curricula which involves computers, we need to insure that the instruction we provide our students will help them in the world of work. It is helpful, therefore, to examine the ways in which computers are used at work now, and try to determine how computers will be used at work in the future.

While it is not entirely clear what school children need to learn now in order to be competent and useful in the 21st century, most computer scientists believe that in a few years very few people will be actually writing computer programs with general purpose languages. Increasingly, microcomputers are being used in business and industry for word processing, spread-sheet analysis, and data systems management--applications which do not require knowledge of general purpose computer languages. These business applications are being implemented, not by highly skilled programmers, but by employees learning to create electronic forms and spread sheets provided by special purpose user friendly programs (e.g., Visicalc, Word Star). Eventually, computers will write programs in response to spoken or typed requests made in ordinary English (Kay, 1983), further reducing the need to produce a multitude of general language programmers.

The shift in computer uses from those dependent upon general purpose programming languages to those using special purpose programs suggests that even though our society may rely heavily on the computer, we will not need vast numbers of programmers. Even though there is a shortage of general purpose programmers now, we are likely to need far fewer in the future.

The available evidence suggests that most jobs will not be found in high technology industries, nor will high technology require a vast upgrading of the American labor force (Levin and Rumberger, 1984). On the contrary, the proliferation of high technology industries is far more likely to reduce the skill requirements in the U.S. economy than to upgrade them.

Levin and Rumberger (1984) cite Labor Department projections that say jobs for computer programmers will grow between 74% and 148% during the 1980s, while overall job growth will be only 22%. These percentages are misleading, however. The total number of new jobs for computer programmers is expected to be 150,000. Some 1.3 million new jobs are projected for janitors, nurses aides and orderlies. That is nine unskilled jobs in these categories for every computer programmer. New jobs for data processing machine mechanics will increase 148%, the fastest growing job category. But that large gain translates into an increase of fewer than 100,000 new jobs, while 800,000 new jobs are projected for fast-food workers and kitchen helpers alone.

There will neither be a proliferation of systems analyst jobs, nor will the high-tech jobs create demands for increasingly sophisticated work skills. On the contrary, the new technologies further simplify routine tasks and reduce the opportunities for worker individuality and judgment. In such diverse areas as office administration, data processing, drafting, and wholesale and retail trade, microcomputers are making it possible to employ persons with lower skills to perform what had previously been highly sophisticated jobs.

The results of this brief examination of the use of computers in the world of work have implications for the widespread teaching of programming presently pervading our curricula. Strictly on intellectual and academic grounds, it may be important for students to gain some exposure to programming. Indeed, programming may enable students to gain a sense of how the computer operates and develop some skills in structuring problems. But, devoting years of a student's time to programming instruction can not be justified on the grounds that we are providing skills that students will require professionally (Tucker, 1983). We may need tens of thousands of general purpose programmers, but not the millions we will be producing with the current emphasis on programming in schools (Levin and Rumberger, 1984).

Instead of making programming the single entry point and the pinnacle of computer education curricula, it is important to provide students with "multiple entry points to expertise" (Levin and Souviney, 1983). Multiple entry points will enable students to use computers as powerful tools for a wide range of applications. For some students, that power will first develop through the ability to program the computer. But for others, that power could come from first knowing how to use the computer to write and edit text, to create music, graphics, and animation, and to organize information and communicate it to others.

Our Approach to Finding Solutions

Our overall goal as we work with computers in education is to address the three main problems in current computer use: (1) the underutilization of the computer's capabilities, (2) stratified access, and (3) the single avenue to the world of computing through programming. In the remainder of this chapter, we describe the approach we are taking to meet our goal. We describe some of the ways in which learning environments can be assembled that take advantage of the interactive capabilities of computers. The curricular activities used in the classrooms in this project were produced by a unique collaboration between school teachers and university researchers. A discussion of this collaborative effort follows our description of the design features of functional learning environments.

Exploiting the Interactive Capabilities of the Microcomputer: Creating Functional Learning Environments

One way to use computers to achieve equitable access and unique educational goals is to exploit the interactive capabilities of microcomputers for language arts and mathematics instruction. The availability of word processors, writing tools, computer labs and computer networks makes it possible to create learning environments which go beyond drill and practice and programming.

As we will point out in Chapter 4, microcomputers can be arranged to provide a communal resource to students, the use of which is not predetermined, but can be changed by students and teachers during the course of interaction itself. Interactive software enables teachers and students to modify the learning activity as instruction progresses. The open-ended character of learning environments such as LOGO (Papert, 1980), the PLATO mathematics lessons (Davis et al., 1977), and construction sets such as "Rocky's Boots" (The Learning Company), encourage users to build their own materials and see what happens by selecting components and connecting them. As students explore these activities, they move in directions not originally planned by teachers, thereby learning that problems have many solutions, not a single solution which is provided by the teacher.

Rather than looking at microcomputers as dispensers of certain knowledge or rewards, we explore ways to organize functional learning environments. The functional learning environments we have constructed in language arts and mathematics (see chapters 6, 7 and 8) (1) adopt a holistic approach to educational practice and (2) provide dynamic support to novices learning a task.

The Whole Task. A fundamental component of our approach to computer use is the belief that children learn most effectively by participating in _whole_ activities with others. Through this participation in the whole task, others perform some aspects of the task which are too difficult for the children to accomplish on their own; in time, the children learn how to master the entire task alone (Luria, 1976; Vygotsky, 1978; Wertsch, 1979; Flavell, 1981; Griffin and Cole, 1984; and compare Piaget, 1970).

The _holistic_ emphasis in our work contrasts sharply with _atomistic_ educational practice. Children most typically work alone on subparts of a task in schools. When students accomplish all the subparts, they are expected to assemble these components into a unified whole _on their own_. In many standard reading programs, for example, children begin work on recognizing letters, establishing sound-letter correspondence and blending letters together to "read" words and sentences. These activities often occur in isolation from reading presented as a method for learning new things from text. Or, when students are asked to write compositions, they are first asked to write sentences, then paragraphs, and finally complete essays.

A clear example of the holistic approach to educational practice, and one many of us are familiar with, is the way parents teach their young children how to read (Ninio and Bruner, 1978). From the beginning, the social setting is parent and child, and the activity is reading a book. Initially, the child knows very little about the activity of reading and the mother must carry much of the work. As the child becomes familiar with the patterns, he or she may begin to participate in simple subskills such as turning the pages, or pointing to objects. As the child gains knowledge, what is expected of him or her shifts. Now the child is asked to provide names for objects or to tell what is happening in the story. Slowly the attention is shifted from pictures to words and the child begins to recite well learned pieces of the story. This skill becomes more and more flexible as the support provided in the book and by the mother recedes, and the child becomes an independent reader.

The activity has remained constant through the whole process: parent and child sitting together reading the book. What has changed is the degree of participation in the activity on the part of the child. This dynamic network of support has been referred to as "The Zone of Proximal Development" (Vygotsky, 1978; Brown and French, 1979; Griffin and Cole, 1984). The activity that is accomplished by the mother and child ("the zone"), provides a good prediction of what the child will soon be able to accomplish on his or her own at some future time. Learning to do the pieces in the context of the whole guards against becoming so obsessed with accomplishing subgoals that the student never understands the relationship of the subparts of those actions to the whole task.

In short, we have drawn a parallel between a holistic approach to teaching reading (LCHC, 1982) and a holistic approach to learning to use a microcomputer. In doing so, we have found that microcomputers can be used to provide children support for elements of writing tasks they have not yet mastered. Furthermore, this support can gradually be removed as the children become more skillful, as we describe in the following discussion of "dynamic support."

Dynamic Support. "Dynamic support" refers to the process of systematically decreasing amounts of assistance provided to novices as they progress in expertise and gradually assume parts of the task initially accomplished by an expert. In a properly arranged teacher-student-computer environment, there is potential for creating the kind of dynamic support necessary to dramatically improve students' learning.

Riel (1982) showed that the microcomputer can provide dynamic support to students with language disabilities. She found that children with language handicaps had greater difficulty than students with normal language development in making efficient problem-solving decisions when playing computer games. In a training study, Riel modified the computer software so that at first, most of the game parameters were controlled by the computer. As the players' skill increased, this support was gradually withdrawn. After several weeks, the game performance of the students with language handicaps was similar to that of normal students. In this way the computer was used to construct a "Zone of Proximal Development" which provided training in a variety of systematic, self-regulatory problem-solving skills as children learned basic materials.

Software is now available which, like the parent in the Ninio-Bruner reading example, systematically increases the degree and form of learner participation as skills develop. For example, in text editing systems such as QUILL (Bruce and Rubin, 1983), and The Interactive Writing Tools (Levin, 1982), texts are constructed which share the initiative between writers and readers along a continuum of support (Riel, Levin and Miller-Souviney, 1984). This continuum of support is shown in Figure 1.

Figure 1

A Continuum of Educational Software (from Riel et al., 1984

Program Controlled	Mixed Control	User Control
<--------------------	--------------------	-------------------->
Static Frames with Fixed Content	Lesson Frames with Content Added	Open Frames with Variable Content

At the program-control end of the continuum, "readers" of structured interactive text are invited to make simple choices about the direction in a story's plot. At the user-control end of the continuum, an interactive text or planner enables more skilled writers to take complete responsibility for writing. At the user-controlled end of the continuum, the computer offers high-level suggestions and provides prompts, leaving the lower-level writing activities in the hands of the student. Such writing tools make it easy for students to enter text by providing activities which range in the degree of support. Perhaps more importantly, they make it so easy to make changes in text that elementary school students can edit their writing as a functional everyday activity. Throughout these activities, the goal is for the quality of writing to remain constant while the participation of the learner increases, as the amount of support provided by the computer decreases.

Dynamic support provided by the interactive capabilities of the computer subordinates the students' concern for the mechanics of tasks to higher order goals. By arranging learning environments in which computer based support is gradually removed, students gain control of learning by systematically assuming the components of the task initially accomplished by experts, in this case, represented by a teacher-computer configuration.

Teacher-Researcher Collaboration

While some of the sources of inequities in our society may best be attacked by change in organizational structures or by change in technology itself, we chose to affect change by a teacher-researcher collaboration because teachers are in closest contact with students and computers. The collaboration involved the systematic introduction of computer curriculum in a small number of classrooms accompanied with supporting knowledge and training. The computer curriculum was an extension of previous work conducted at UCSD to teach basic skills to small groups of specially selected students in resource rooms and after school clubs (LCHC, 1982; Riel, 1983; Levin et al., 1984). In this research project, we extended our educational efforts in two ways: first, to the education of a more diverse population of elementary school students; second, to operate within the the constraints of regular classroom configurations and educational curricula.

The classrooms had diverse student populations in terms of age, measured ability, socioeconomic background and ethnicity (more details about the classrooms are provided in Chapter 2). The grade levels ranged from 2nd to 6th grade. The students' abilities were measured from the lowest CTBS quartile to GATE qualification. One classroom was part of a designated bilingual program, two others had a number of students who spoke Spanish as a first language and one was designated as a Chapter 1 classroom.

The teachers were involved in every stage of the project. The work was done collaboratively because expertise is distributed across the members of social groups. Our group dealt collectively with the issues that were crucial in determining how the computers would be used in the classroom. Some of the ways in which teachers guided the research are discussed in the following sections.

Evaluating Student Progress. Teachers took an active role in deciding what measures to use to determine student progress. They described the school administered standardized testing (CTBS) and Ginn reading level scores that would be available. The teachers and researchers worked together to design a set of pre- and post tests to measure the students' reading and writing skills.

Selection of Software. At the outset of the project, teachers were asked to formulate their teaching objectives, especially in the curriculum area in which they would be using computers. After teachers described their objectives, computer software was discussed in light of teacher goals. Both teachers and researchers were concerned about how to use the computer to facilitate forms of interaction and learning that are different from the interaction that conventional forms allow. It was decided that all the software used on the project would be either "tool software" (i.e., software in which the goal is provided by the user and the software is used as a means to accomplish the goal) or software that encouraged discovery of conceptual skills.

Software that meets these criteria were discussed. Previous models of integrating software in teaching environments were presented by the teachers who had some experience with computers and reports were made by researchers about how software had been used in other research projects. Teachers decided which software they would use in their classrooms. The instructional activities that are described in Chapters 6, 7, and 8 were created by teachers as they experimented with integrating software with their teaching objectives.

Participation in Computer Chronicles News Network. Three teachers decided to make newspaper reporting and editing a central focus of their language arts curriculum. These teachers enrolled their students in the "Computer Chronicles News Network." The teachers who were not familiar with the software were encouraged to spend time writing and editing stories in the same manner as their students.

The teachers worked together and with members of the research team to formulate their plans for using the Computer Chronicles in their classrooms. For example, teachers discussed students' choice of writing assignments. One teacher felt that free choice would increase motivation. Past experience indicated that the newspaper sections devoted to jokes and sports would be very popular selections if students were given free choice. The teachers were concerned with ways to encourage diversification. One teacher decided to provide more structure to the newspaper activity by assigning topics to the student reporters, pointing out that "cub reporters" never get to choose what they write about. Each of the teachers formulated a method of making newspaper assignments. Reports of successes and failures at project meetings helped the teachers find the most productive solutions.

The teachers organized means for evaluating, selecting, editing and doing the layout of their newspapers once stories were written and received from other schools on the network. The production of newspapers was discussed by teachers and researchers. Ideas of ways to adapt the "editorial boards" previously used in a resource room version of the Computer Chronicles to the classroom were generated. Two of the teachers decided to have a number of different boards, one for each newspaper edition, and keep the size small. Another teacher decided to have all the students participate in the production of each newspaper by dividing the class into small board meetings for each of the different sections of the newspaper. A third solution made the selection of stories into a reading center task.

The use of editorial boards led to discussions about the organization of editing in classrooms. The problem of coordinating stories once cut up and placed in folders according to sections and stories stored on disks was discussed. Solutions ranged from those that placed a major responsibility on the teacher to those that required more training of the students.

Data Collection and Observations. The teachers worked closely with the observers to determine which classroom activities to observe and tape. We adopted data collection and observation techniques that we have found to be productive in our previous projects (Mehan, 1979; Riel, 1982; Moll and Diaz, 1984). We agreed that observations would be made three times a week during the time that the central focus of the classroom occurred. We reduced the number of observations to two a week in January. The events to be videotaped were selected based on their coordination with other classroom activities and the production of a student's "product," i.e., a document. All observation notes taken in classrooms were made available for teachers to read. All videotapes were available for viewing, and teachers retained the right to end any taping sessions and erase any videotape.

The operating principle of the project was that teaching goals would have priority over research goals. Activities that were of special interest to the project were described and teachers were requested to report when such activities took place in their classrooms. Teachers made special efforts to arrange their teaching schedules to make it possible for researchers to observe particular activities. Despite these special efforts, observers still needed to work around the needs of the teacher and constraints of the curriculum. The teachers were invaluable informants, highlighting activities that might have gone unnoticed if the observers had made unilateral decisions about observations.

Data Analysis. The teachers took part in discussions of the material to be collected, how it would be analyzed and participated in data analysis. The teachers collected samples of students work in language arts and mathematical problem solving at regular intervals throughout the school year. For each of these samples they provided their guidelines for evaluating student work. Writing samples were scored according to the guidelines established by the teachers. Funds provided by NIE enabled the teachers to serve as Research Assistants during the summer after we gathered data in the classrooms. During the summer, the teachers participated in videotape viewing sessions. In these sessions they watched videotape from their classroom and worked with researchers to organize a coherent picture of classroom events. They collaborated in the preparation of some of the chapters in this report (see Chapters 3, 4 and 9). Three of the teachers will continue the analysis of materials gathered from their classrooms as part of an MA program at UCSD.

Summary

These are some of the ways in which a group of elementary school teachers and university researchers have worked together to seek effective ways to utilize microcomputers in schools, and to do so in ways that provide equitable access to all children. Observation of and participation in the implementation of these programs has provided us with valuable knowledge about the degree and kind of help students and teachers need to use computers in classrooms, ways to organize classrooms for instruction with computers, patterns of teacher-student interaction and students' learning. We report the results of this collaboration in the following chapters.

CHAPTER 2

THE CLASSROOMS

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The research took place in four classrooms in the "North County" area of San Diego. The curricular emphasis in three of the classrooms was language arts. Therefore, we focused research attention on that area in those classrooms. In the fourth classroom, the teacher experimented with teaching problem solving using direct instruction techniques, manipulatable materials and computer programs. We documented the results of this experiment conducted in a computer lab and classroom.

The following pages describe the organization of instruction in the four classrooms. This overview is provided to orient the reader of this final report to the analysis which occurs in subsequent chapters.

The Organization of Barbara Miller-Souviney's 4th Grade Classroom

BMS' class was a fourth grade in which there were twenty-six students, thirteen boys and thirteen girls. The class was considered to be the fourth-year (mainstream year) of the school's K-3 bilingual program. Six students

(23% of the class) were past participants of this program. There were two aides in the class (funded by SIP and Chapter 1 funds): DT worked with all the children on both math and language arts in the morning. Another aide, MV, came four days a week for 45 minutes a day and worked on language arts with primarily the bilingual students.

The classroom was in a temporary building physically removed from the other, permanent buildings. The room was large and carpeted. BMS asked for the room particularly because she wanted an atmosphere that way away from other, "traditional" classrooms and the flexibility of the furniture arrangement that came with the temporary building.

Students were seated at four rectangular or circular tables. Students' belongings were stored in individual plastic tubs. BMS established this arrangement in order to accommodate both instruction and student seating in the same area.

The walls around the classroom contained charts and information that were used within the day's activities: a daily schedule, VIP of the week, spelling lists and typing paper, a daily class history, sustained silent reading directions, computer rules, a giant replica of an Apple //e keyboard made of styrofoam cartons, a height chart, calendar, "We Have Rights Chart," class groupings, and students' work.

The classroom was organized into activity centers. There are three centers called Station 1, Station 2 and Station 3 (see Figure 2). These were not additional areas but transformations of the students' seating areas, so

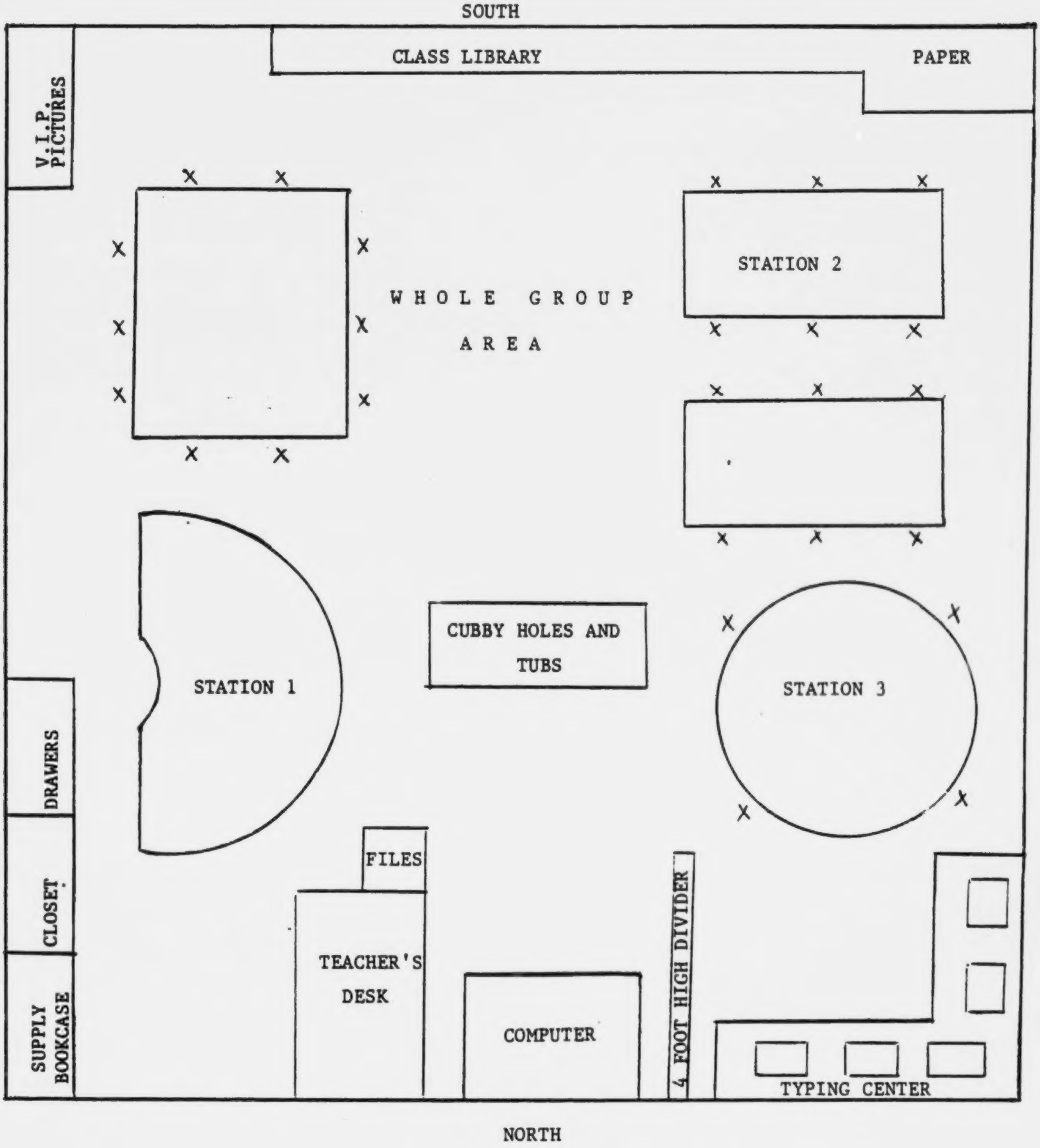

SOUTH
CLASS LIBRARY
PAPER
V.I.P. PICTURES
WHOLE GROUP AREA
STATION 2
STATION 1
CUBBY HOLES AND TUBS
STATION 3
DRAWERS
CLOSET
SUPPLY BOOKCASE
FILES
TEACHER'S DESK
COMPUTER
4 FOOT HIGH DIVIDER
TYPING CENTER
NORTH

FIGURE 2
Olive School Classroom 4th Grade

that the kidney shaped table became Section 1, the rectangular table became Station 2, and the circular table became Station 3. The "computer center," where the classroom's one computer was located, and the typing corner (with five old typewriters) were a sub-set of Station 3. There was also a "whole group" area (the floor space in the center of the room).

The computer was located against the north wall of the classroom under the windows. It was on a moveable cart that contained all the necessary hardware and software: Apple //e computer, one disk drive, monitor, printer, and disks. It was somewhat isolated from the rest of the classroom by the arrangement of other classroom furniture (tub, bookshelves, teacher's desk, divider/display boards). Students working on the computer had their backs to the rest of the class. The area was fairly spacious, however, and the teacher could see the computer screen from her usual location at Station 1.

Students were placed into ability groups for language arts and math in the beginning of the year. Ability grouping was done on the basis of assessment tests that BMS administered herself, along with the recommendations of the previous year's teacher. Wall charts listing the students' names and the math and language arts groups were located above the blackboard. The scheduling and rotation of the students through the stations depended on these groupings which were flexible, and subject to change during the school year.

The Daily Schedule

7:30	School starts.
7:40-8:00	Whole group meeting in whole group area. This is the time for 1) News, 2) Things to Share, 3) Announcements, and 4) Questions.
8:00-9:00	Math. On Monday and Friday, whole class activities are conducted. On Tuesday, Wednesday and Thursday, the students rotate through the stations at 20 minute intervals. Monday through Friday, pairs of students are scheduled on the computer for 20 minute sessions.
9:00-9:30	Writing (pencil-and-paper). Whole group instruction that breaks into individual or small group work.
9:30-10:00	Nutrition and Recess.
10:00-11:25	Language Arts/Science/Social Studies. On Monday and Friday, whole class activities are done. On Tuesday, Wednesday and Thursday, the students rotate through the stations at 25 minute intervals. Monday through Friday, pairs of students are scheduled on the computer for 25 minute sessions.
11:25-11:40	Oral Reading. Teacher reads out loud to whole class.
11:45-12:30	Lunchtime.
12:30-12:55	Sustained Silent Reading. Students and teacher read silently.
12:55-1:15	P.E. (Physical Education).
1:15-1:30	Class History. Whole group activity. Students review what they did during the day. VIP of the week writes it on a 3x5 card that is placed on the Class History wall display.
1:30	School ends.

Writing Activity. Writing was an integral part of this teacher's curriculum prior to the initiation of this project in her classroom. This emphasis led us to concentrate attention on language arts when the computer was introduced into the classroom. During the writing activity that took place from 9:00 to 9:30 everyday, students wrote with paper-and-pencil. The computer was not used during this time.

BMS' classroom instruction in writing focused on the writing process which includes the following phases: pre-writing, writing, response, revision, post-writing, and evaluation. The length of time it took to complete a writing project varied from one to four days and depended on the goal of the project. Writing for the development of fluency focused on pre writing and writing only, whereas writing for a class book or a class newspaper included all stages. During writing time, BMS either wrote along with the students or she walked around the classroom providing help as needed.

BMS initiated a writing project with the class as a whole. The class is called together at 9:00 to the whole group area where BMS introduced the topic and conducts a pre-writing activity. During the year, this included clustering words on the blackboard or a big sheet of paper, brainstorming ideas about content or titles, reading examples, drawing pictures, etc. Students returned to their seats to carry out a particular pre-writing activity, or, if sufficient time had been spent on pre-writing, the students began the writing stage of the process.

During the writing stage, BMS emphasized that they are writing only a first draft and they shouldn't worry about spelling or punctuation at this time; those issues were focused on during later stages. Students were given a certain amount of time to write (approximately 10-15 minutes) and a timer was set. Students wrote individually, but occasionally consulted BMS or peers for help. During this time BMS wrote herself or helped students, for example, or wrote spelling words on the board.

When writing time was finished, BMS either collected the papers marking the end of the session, or, if time allowed, she asks for volunteers to share their stories with the class. She asked the rest of the class to listen to the story and think about what they like about it. Students were often eager to share their writing and BMS chose from a number of raised hands. After a student read his or her story, the other students responded informally to the writer regarding what they liked about the writing. Responding students were generally called on by the writer (or by BMS if the writer didn't seem to be doing it). The writer also chose the next person to share his or her writing.

The third stage, response, was also conducted in a whole group. BMS began the session by reviewing the phases of the writing process they completed thus far: clustering and writing. She then wrote a short segment on the blackboard of an anonymous student's paper. She asked how to make the segment "even better." Students raised their hands and were called on individually. They pointed out spelling errors, missing punctuation, or ways to make two sentences out of one long one. BMS showed how to make changes by correcting the segment on the blackboard: the change or mistake was circled so the writer knew what it was, or the correct spelling or punctuation was written on the paper.

BMS then divided the class into editing groups for response. Each table usually made up an editing group. She gave each table 3-5 papers with the directions to read the story and edit it. Students read and edited individually. When a student completed one paper, they were to read another one, until they had read all of the papers assigned to his or her group. If the students had problems reading the writer's handwriting (which they often do) they were to ask the writer about the word. If they did know how to spell a word, they were to use the dictionary or ask a peer. During this phase, BMS walked around the room and helped or directed students to other resources. This phase of the writing process was characterized by a lot of peer interaction/consultation and walking across the room to the original writer. Once again, the timer was set for a limited amount of time for the editing process.

The fourth stage, revision, begins as edited papers were returned to the writers along with clean "white" papers (beige wood-pulp papers were used for the first drafts). Students rewrote their papers for the final draft. BMS reviewed revision guidelines which included assessing the editing suggestions that were made, consulting with the editor about the reason for particular corrections (if they were questioned), looking up spelling errors, and recopying the paper in legible cursive writing. Students worked individually at their tables, occasionally consulting peers or BMS as she walked around the room.

When the revision/recopying was complete, the papers were assembled in a public way for the post-writing stage of the process. They were hung on the wall in the classroom or put together in a class book. The whole writing process from the beginning to the end of a particular project usually took four or five days to complete.

Language Arts Instruction. Language Arts instruction occurred from 10:00 to 11:25 daily, but the structure of the activity varied according to the day of the week. On Monday and Friday instruction was generally in whole group form or a variation of ability groupings. On Tuesday, Wednesday, and Thursday, students rotated between the three stations in 25 minute intervals. The computer, however, was used daily by scheduled pairs of students for 25 minute intervals (duplicating station-rotation scheduling).

BMS prefaced the language arts period with a description of the introduction activities for the day. This introduction took place in the whole group area. It was particularly important for Station 3 where students worked independently. A thorough demonstration of the computer activity for the week took place on Mondays (and as necessary during the rest of the week). Students gathered together at the computer center for this demonstration. Before station-rotation began, BMS reviewed the day's computer assignment and, if a scheduled partner was absent, another one was chosen by the designated student.

Station Rotation: Tuesday Through Thursday. As mentioned earlier, the classroom was divided into three work stations. In general, Station 1 focused on reading comprehension activities with the direct involvement and presence of the teacher. Station 2 focused more on English, Science, and Social Studies activities. Activities planned by BMS were coordinated by the teacher's aide (DT). Station 3 activities focused on spelling and were independent of direct adult supervision. The computer activities (a sub-set of Station 3) focused on writing and were frequently under the observation (although not the direction) of a project researcher.

Scheduling for station-rotation was established in the beginning of the year and was changed for curricular reasons during the year. Students were placed in three ability groups of approximately nine students each: Orange Group, Purple Group, and Green Group. Students' names were written on a sheet of appropriately colored construction paper and the lists were placed in a row above the blackboard (from left to right: Orange, Purple, and Green).

When station-rotation began at 10:10, the Orange Group went to Station 1, the Purple Group to Station 2, and the Green Group to Station 3. At 10:35, the teacher rang a small bell indicating the end of the first session. Students completed their activity and waited for the next bell to signal the next rotation. Students rotated clockwise around the room so that Orange Group went to Station 2, Purple Group to Station 3, and Green Group to Station 1 (refer to Figure 2). This cycle was repeated at 11:00, completing the rotation of all students through all of the stations.

There was also a schedule placed above the computer that indicated the pair of students to be on the computer during each 25 minute interval. Since the computer was a sub-set of Station 3, students were scheduled onto the computer when their group rotated into Station 3. Therefore, two students from each ability group used the computer each day.

Typical activities at Station 1 included use of the Weekly Reader, reading plays, poems, booklets, etc. BMS stressed higher level reading comprehension skills such as inferencing and sequencing. Social studies were incorporated into language arts through such topics as safety and decision making.

Station 2 activities involved games or other manipulatives intended for practice with various English skills (for example, punctuation, capitalization, prefixes, vocabulary development, etc.). Station 2 was also used as a follow up to Station 1 (for example, answering questions pertaining to a particular reading activity in social studies and science), and as a seasonal "Holiday Station."

Station 3 activities focused on spelling and writing, including search puzzles, writing stories incorporating all the spelling words, or typing the week's spelling words on the typewriter. Section 3 activities were without the direct supervision of an adult and therefore required some special support materials. For example, on the bulletin board next to Station 3, there was a manilla folder for students' completed work, and another one for typing paper. There was also a paper for students to check off their names when they completed the given activity. Students usually worked on individual activities at Station 3. However peer interaction was abundant and in most cases encouraged (unless the noise level became too high, requiring teacher intervention).

The computer activities focused on writing. Students worked in pairs (which is unlike most of the classroom activities). Support materials giving directions were placed all around the computer: the primary note indicated the program/activity to be done for the week, step-by-step directions on how to operate the word processing program, how to edit text, basic start-up and troubleshooting directions, posters with ideas for writing (pre-writing materials). Since the computer activities were also without the supervision of an adult, students had to solve any problems they encountered themselves, by referring to the support materials or by calling a peer or an adult for help. (There was frequently a research observer nearby who could provide assistance.)

Activities on the computer involved creating stories from pre programmed story parts, writing Computer Pal letters to students in a nearby school, editing poems that students have created, and writing newspaper articles for the Computer Chronicles.

When students completed an activity on the computer they were to print out three copies of the text (two for themselves and one for a file for the teacher). They then checked off their names from the Station 3 list indicating that they had completed the Station 3 activity.

Language Arts: Monday and Friday. Monday and Friday activities were basically whole group activities. BMS began the session on both days at the whole group area, going over new vocabulary words.

At approximately 10:20, students broke into their "Ginn Groups." These groups were similar to the Orange, Purple, and Green ability groups, however they specifically covered the classroom's five Ginn reading levels. During this time, BMS worked with Levels 10 and 11, DT worked with Level 8 and 9, and MV worked with Level 7. On Monday, students were given papers outlining the week's Ginn lesson and related homework. Students began the lesson in their small groups and were to complete it for homework. The lesson included "Skilpak" activities for parents. This work was corrected on Friday during the same time period.

At approximately 11:00 on Monday, Spelling Super Star awards (stickers) were given to students who improved on the week's spelling tests. Following this, the week's spelling words were given in a pre-test. This was basically a whole group activity except for the Ginn Level 7 Group which took a separate test outside with DT. On Friday, a spelling post-test was given during this time period.

During this time, pairs of students were using the computer for 25 minutes. Special arrangements were made for them to complete missed work (if necessary) and get the week's assignments and spelling words.

Summary. This classroom was organized into small groups for the purposes of instruction, primarily small groups were used in all curricular areas, most notably those associated with language arts. Whole group activities appeared twice: once during the teaching of math, and once as a way to introduce language arts activities.

Some of the small groups were supervised directly by the teacher or aides; others were supervised indirectly. In indirectly supervised groups, students were expected to work independently on assignments that the teacher had given to them.

Computer activities were organized as a sub-set of one of the stations during language arts time. A pair of students went to the computer station and carried out instructions that were posted there in a manner analogous to the students who go to a station and work on an assignment independent of the teacher.

The teacher placed considerable emphasis on each student's responsibility for the group's welfare. A theme in her discussions with them and visible when she provided the rationale for or justification of her disciplinary action was: students taking personal responsibility for their actions. If students acted out or were disruptive, the teacher pointed out that their actions made it impossible for others to work, thereby making the entire group less productive. The teacher socialized the students into this norm both privately and publically. She attended to individual transgressions privately, out of the hearing of other students. On those occasions when an individual's or small group's actions had larger consequences, she called the whole class together as a group, and reinvoked the social contract.

The Organization of Bea Liner's 3rd Grade Classroom

Bea Liner's 3rd grade class at Palmquist Elementary School in Oceanside was an English/Spanish bilingual class. The classroom consisted of 30 students, although the number varied depending on the curricular activities (see Daily schedule). Of these 30 students, 10 were considered limited English proficient (LEP) students, qualifying for bilingual instruction. During our initial weeks of observation, from late September to November, Ms.

Liner placed a student teacher who was in training with her in charge of arranging the classroom environment. The student teacher organized classroom desks to form four main groups or stations. To the side of the four tables that formed the stations were a semi-circular table and a large round table where other curricular activities such as science exhibits were located. Within this arrangement the computer was placed against a wall, near the main classroom exit at the rear of the classroom, with the teacher's desk across the class in the opposite corner.

After the student teacher left, Ms. Liner rearranged the classroom into rows: four rows in back of each other, and at both sides of the classroom one long row extending from the front to the back of the classroom. Ms. Liner also moved the computer from its original position by the door to the opposite south-east corner, where the teacher's desk was located previously; i.e., at the front of the class where the teacher conducted most of her activities. Her desk was moved to form part of the long parallel row near the west wall of the class (see Figure 3, below). The computer is partially hidden and isolated from the rest of the classroom by a divider, which also serves as a display board for the computer users. It contained disks, instructions and other relevant information. From her usual position at the front of the class, the teacher had a clear view of the children working on the computer and was able to monitor any difficulties or problems, as well as encourage the students to stay on task.

Ms. Liner was assisted in her teaching duties by Ms. Delfina Zimmerman, a bilingual teacher aide. More than an aide, Ms. Zimmerman functioned as a co-instructor and participated fully in all classroom decisions and

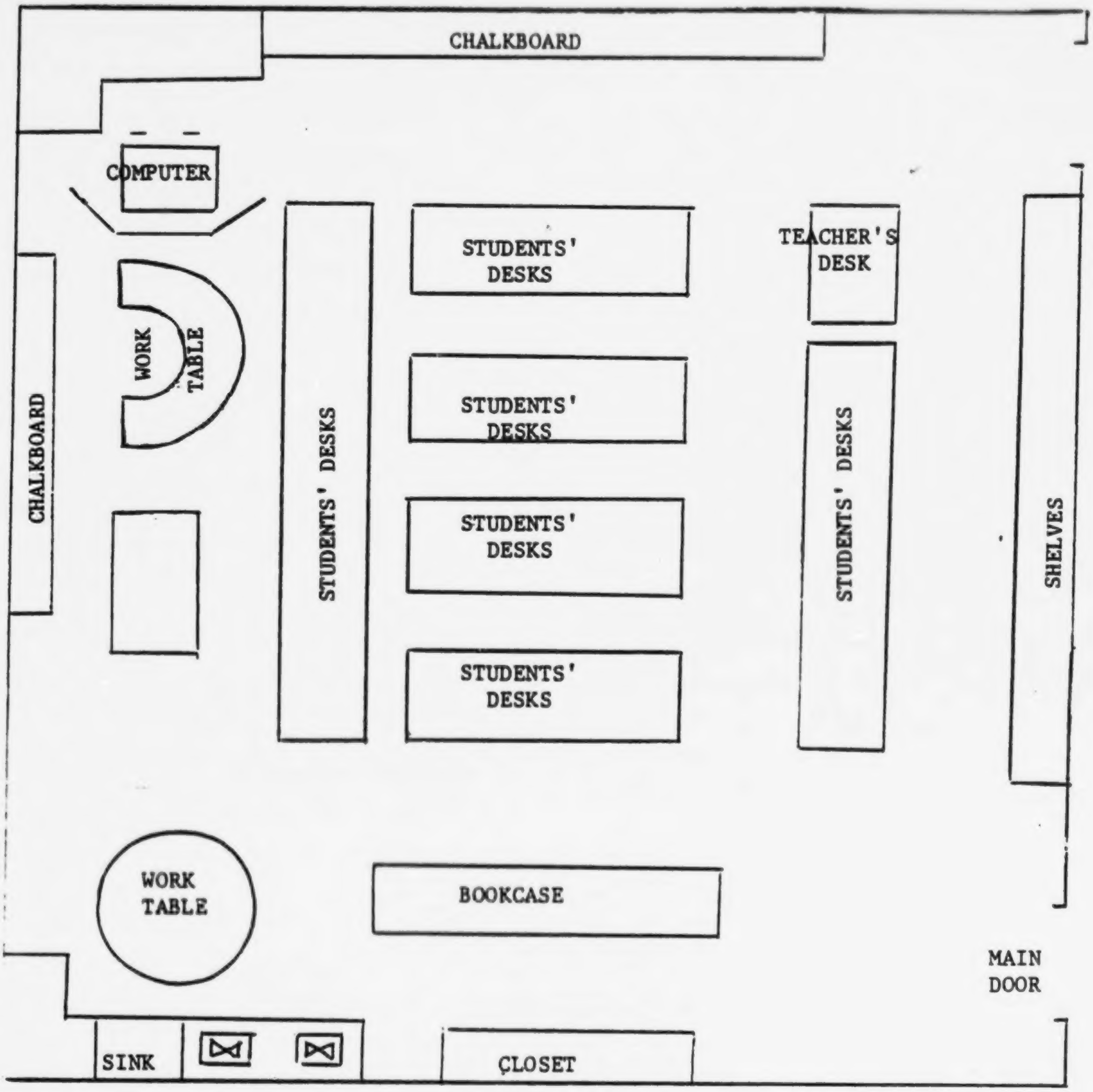

CHALKBOARD
COMPUTER
STUDENTS' DESKS
TEACHER'S DESK
WORK TABLE
CHALKBOARD
STUDENTS' DESKS
STUDENTS' DESKS
STUDENTS' DESKS
STUDENTS' DESKS
STUDENTS' DESKS
SHELVES
STUDENTS' DESKS
WORK TABLE
BOOKCASE
MAIN DOOR
SINK
CLOSET

FIGURE 3
Palmquist School: 3rd Grade Classroom

activities. She arrived at nine o'clock in the morning and immediately took charge of the math, reading and writing lessons with the limited English speaking students. These lessons, which were planned jointly by teacher and aide, were organized into small group activities and conducted in a spacious, round table near the rear of the class. Occasionally, during the course of the day, Ms. Liner, also a fluent bilingual, monitored the lesson activities with the limited English speaking students, and offered suggestions to Ms. Zimmerman. Their emphasis was on team teaching. They met regularly after class to evaluate student progress and plan future activities.

While Ms. Zimmerman conducted her lessons, Ms. Liner taught whole-group lessons to the English monolinguals in the class. Ms. Liner attempted to maintain both groups of students on equivalent tasks. With the exception of the bilingual instructional support provided to the limited English speaking students, all students were exposed to a similar curriculum.

A computer schedule was posted weekly near the computer center. The children were assigned in pairs to use the machine for 30 minute intervals. Thus, each child in the class worked on the computer for at least half an hour a week. Every Monday morning, Ms. Liner described the computer activity for the week and her expectations for the students. She also provided examples of the procedures they were to follow, answered questions and addressed any complaints. The children learned this routine so the rotation of children to the computer proceeded smoothly.

The Daily Schedule. An unusual feature of this classroom was that students are distributed by ability grouping among three different classrooms. For math instruction, Ms. Liner received children classified as high ability from two other classrooms while the children in her class not classified as such moved to other classrooms participating in this arrangement. A similar arrangement was made for reading instruction. In this case Ms. Liner received students classified as low group readers.

The classroom schedule is as follows:

8:30	School starts: roll is taken, assignments submitted, flag salute, etc.
8:30-9:45	Math time: the class composition consist of 20 English monolingual students, 6 Spanish dominant (LES) and 1 Chinese dominant student.
9:45-10:00	Recess.
10:00-11:30	Language arts, reading, spelling and writing: classroom consists of 22 English monolingual students and 10 Spanish dominant students.
11:30-12:15	Lunchtime.
12:15-1:20	Science unit/optional activities.
1:20-1:30	Recess.
1:30-2:05	Physical Education
2:15	School dismissed.

Mathematics. The math group (English monolinguals) consisted of students classified as high ability. Math instruction was organized as a whole group lesson. Ms. Liner stood in front of the class and provided directions, reviewed previous work, and introduced new content. She then provided the children with a series of problems to solve, usually in the form of worksheets. As the students worked on these problems, Ms. Liner moved about the classroom providing assistance as needed.

Meanwhile, the Spanish dominant students, a much smaller group, worked on the tables to the side of the classroom under the supervision of the teacher aide. Occasionally the teacher came by the side tables to check on the students' progress and offered suggestions.

The math book used was Mathematics Around Us, California State Series, level 19-24. Some of the topics dealt with were addition, subtraction, multiplication, division, ratio, fractions and geometry. The Spanish speakers were using Mathematics, D.C. Heath & Co. These children worked on addition, subtraction, multiplication and rounding.

Language Arts. At the start of reading time, the English monolingual children classified as low readers entered the classroom. No such differentiation was made for the Spanish dominant speakers. More or less the same group of students remained in the class throughout the day. The same teaching arrangement described for math prevailed for language arts. Ms. Liner taught whole group lessons with the English monolingual speakers, and Ms. Zimmerman taught a small group lesson with the Spanish dominant students. The instructional plan for the Spanish dominant students included reading in Spanish (all of the students were reading beneath grade level), while they were being introduced to reading in English.

The entire school used the Ginn Reading Series. The English monolingual students were at Level 8: Give Me A Clue and the corresponding workbook. The Spanish speakers used the Santillana series in Spanish. They were at the

Adelante level. When reading in English they were at Level One of Ginn: One Potatoe Two.

In addition to reading the students also worked on spelling, dictation and grammar. Ms. Liner introduced them to writing paragraphs. Every Friday the entire class wrote a short paragraph. For grammar lessons, the class used the McMillan English and the skills practice book that accompanies it.

Science and Optional Activities. The activities varied in the afternoon. Sharing time usually started off the afternoon activities. Children brought items or anecdotes to share with their classmates. This time slot was also used for science. They used a book called Concepts in Science 3. The children read silently a book of their choice for about 15 minutes. The children were later asked to discuss their reading with their classmates.

The Computer Corner. The children were introduced to the computer using a program called Apple Presents Apple. When Ms. Liner realized that students interrupted her often if something went wrong, she designated two students as "computer experts" to help other students who had questions or were experiencing difficulties. This strategy did not prove to be successful, as the students continued to rely on the teacher for help and rarely turned to more experienced peers. (This topic is discussed in more detail in Chapter 5.)

During the final week of October, Ms. Liner started assigning computer activities specific to math or reading and writing. For the most part, math activities consisted of multiplication drill and practice exercises. During reading and writing children practiced spelling and used a program called Storyland to compare stories. This program was used in Spanish and English.

The Organization of Robert Rowe's 6th Grade Classroom

Mr. Rowe's sixth grade classroom, like Ms. Liner's 3rd grade classroom, was situated in a math-science magnet school. The magnet school was established as part of a voluntary desegregation plan. The students in this classroom were from diverse backgrounds. They had been identified as belonging to a variety of special education student categories: from the educationally gifted to those requiring extra assistance due to language or physical handicaps. The mixing of a diverse group of students in this classroom demonstrated an emphasis on mainstreaming and an egalitarian acceptance of students' differences on the part of the school and district.

This school incorporated ability grouping with the mainstreaming of special education students through the use of the homeroom concept. The homeroom represented a method of bringing diverse student populations together while ability groups separate students according to performance levels based on standardized tests. Two content areas, reading and mathematics, were organized according to ability groups. The students reported to their homeroom at the beginning of the school day before dispersing to other classrooms which have homogeneous ability groups.

In each grade the students were grouped into three levels within each content area. The three teachers at a given grade level each had one ability group (level) rather than being assigned a heterogeneous student population within his or her own classroom. As a result of this policy, students changed classrooms, being responsible for taking the appropriate books, homework papers, and supplies with them. These rotations between classrooms occurred during the morning hours which were traditionally reserved for teaching reading and mathematics.

The Daily Schedule. The class schedule for this sixth grade was more structured in the morning (which revolved around group work) and more flexible in the afternoon (which allowed more individual study). Friday substituted a "study hall" for the morning math and reading hours. The daily schedule was:

8:30-9:00	Homeroom students (problem solving/journal writing. computer time for pairs activities).
9:05-10:00	Mathematics students (large group--computer time activities).
10:00-10:10	Recess.
10:10-11:10	Reading students.
11:10-11:25	Recess.
11:25-12:00	Homeroom students (journal writing/problem solving activities on computer).
12:00-1:00	Lunchtime.
1:00-2:40	Homeroom students (computer time for pairs). The school-wide goals for collective group and individual goals for the students are in evidence within this particular classroom.

Student Responsibility. This teacher emphasized responsibility to oneself and to the group along with individual achievement. His students were expected to work during the allotted time in class and take home anything they did not finish as homework. Students showed various levels of task engagement; however, RR did not single out disengaged students unless their behavior disturbed others. Time was provided for students to work on assigned homework. On successive mornings students were expected to answer the roll call with the response "complete," if they finished and returned their homework, or "incomplete," if they had not. The teacher explicitly emphasized responsibility when the lesson included group work. RR pointed out that no one student should do all the work for the group; they should share ideas and think about the problem together. Group work was given sufficient class time with each day having a specific subgoal to be achieved. One objective implicit in the teacher's presentation of the group lessons related to the process of systematically outlining a project and attacking the project bit by bit. Each group was entrusted with dividing up the bits in any way they chose as long as it was equitable.

The Organization of Mathematics and Problem Solving Instruction. The focus of our research efforts in this particular classroom were mathematics and problem solving. In these two areas, this teacher used whole group instruction followed by small groups or pairs working cooperatively. Typically, the teacher presented a lesson to the entire group. He discussed the various skills to use to solve the problem or perform the mathematical calculation. After a discussion of this work, the students worked on the assignment with others. The students were allowed to move around the room in order to form work groups. Although students were encouraged to work with others, except on a few occasions specified as individual work, they could choose to work on their own. Rare instances of behavior problems were solved by the teacher. He required the student to work independently, without the support and input of peers. This teacher had excellent rapport with his students and such disciplinary actions were infrequent. BR's teaching style was spontaneous, weaving the students' remarks into the lessons, often using their remarks to demonstrate the practical application of knowledge.

Originally the problem solving activity, which became called "the Problem of of the Week" opened the school day. The teacher dispensed with administrative details as quickly as possible and moved into the "problem of the week" without delay. This tactic worked well when the problem solving puzzles were relatively simple--i.e., without conditions which students freely interpreted in unique and unexpected ways. However, once the activity was established and the problems more complicated, the teacher felt this original time slot was too short and constrained the students' activity. The limited amount of time which remained after the necessary homeroom activities seemed to dampen the students' creative expression and increase their frustration. This constraint was resolved by moving the problem solving time to the 11:25-12:00 slot between the second recess and lunch.

Problem solving instruction focused on several skills: 1) understanding initial conditions; 2) understanding the manipulations required to arrive at a response; 3) visualizing--either concretely or abstractly--the problem and articulating that vision; 4) systematically representing this process-e.g., identifying patterns, predicting possible answers according to the pattern. These skills, often considered steps in the "scientific method," were discussed continually as part of a method for achieving goals (or answers). Trial and error was an accepted method either because the student did not yet possess more sophisticated skills or because the problem did not lend itself reasonably to another method. However, the trials were to be ordered and recorded according to an articulatable criterion which lead more skillful students into "varing one thing at a time." Although the emphasis was on systematic problem solving, the activities were free flowing and not patterned according to predetermined steps. Students were encouraged to explore, think, create, and test their ideas rather than follow a rigid pattern of steps.

Classroom Layout. The classroom was located in a ranch style, single story school building in which some classrooms had a movable partition along one common wall. This classroom had a moveable divider along the east wall. The classroom on the other side of the divider had been transformed into a "computer lab." This teacher also had responsibility for this special resource room. These responsibilities included: organization of the lab, organization of the software, teacher in-service, cataloging software systematically according to types of curriculum objectives each program covers, and administrative duties--i.e., budget, ordering software and other computer materials, etc., presenting information to the district, parents, and other interested parties (see Figure 4).

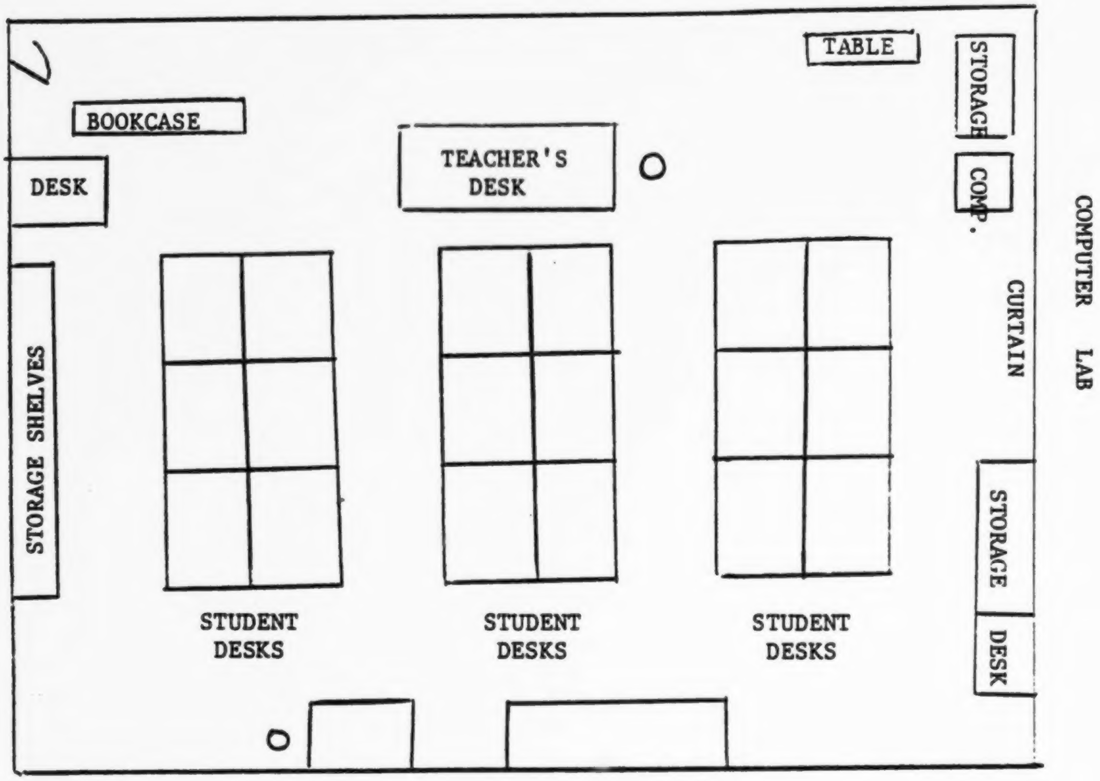

7
BOOKCASE
DESK
TEACHER'S DESK
TABLE
STORAGE
COMP.
COMPUTER LAB
CURTAIN
STORAGE SHELVES
STUDENT DESKS
STUDENT DESKS
STUDENT DESKS
STORAGE
DESK

FIGURE 4:
Palmquist School 6th Grade

There were seven bulletin boards set up in this room:

1. Creative Computing
2. Art Work - "bark pictures"
3. Space Station

4. Word Wall
5. Mind Benders and Brain Teasers
6. Game
7. U.S. map

The left-hand corner of the black board, located in the front of the room, sported a bright yellow sign: Assignments. Under this sign were written the day's classroom and homework assignments.

The Computer Lab. This teacher had time allotted to him in the computer lab four times per week for 30 minutes. Occasionally, he utilized the computer lab for his class when it was empty during the math period. This math group was the lowest ability group and the students need practice at computations. The software available contained a number of computation and estimation programs which the students enjoyed along with a few they found uninteresting.

Summary. This teacher taught his class as a whole group, followed by individual work with students working alone or in small groups. Occasionally, the class was split into two large groups in order to accomplish two activities simultaneously. The groups spent one half of the available time on each activity. Lessons involving two activities were split spatially by using the computer lab next door as the second classroom. The focus of teacher-student interaction was on individual students. This focus fits the classroom emphasis on responsibility and the diversity of its students.

Students worked on the lesson activities after the large group presentation. During these work periods, the teacher and his aide assisted students by privately answering questions and giving encouragement. Public recognition was given to student ideas which served as models or clues (as the teacher called them) for others. The emphasis on responsibility and cooperation was evident during these work sessions. The teacher did not assign workmates or ways to divide up the task. The students were allowed these decisions. However, the teacher gave clues and publically recognizes students who discovered effective cooperative measures.

This teacher wove analytic problem solving skills throughout his lessons. Emphasis was placed on systematic approaches which produced results. Recognition was given to the trial and error method while introducing students to other approaches. Time management was stressed both as a student responsibility and as part of a systematic method for achieving goals. Lesson activities were discussed as whole activities and then as component activities. These component activities were implicitly organized in an adult fashion; but, the students are allowed to attempt them according to their own logic.

The computer lab represented an extension of this teacher's instructional style. Computer lab activities were presented to the whole math group before they entered the lab. Once in the lab, students worked individually or in pairs. The teacher or an adult aide was available to answer questions, make suggestions and guide the students. Students assisted each other whether partners or not by sharing ideas. The teacher brought good ideas to the attention of the whole group. The atmosphere in the computer lab was cooperative--both towards humans and machines.

The Organization of Kim Whooley's 5-6th Grade Classroom

Garrison is an elementary school located in a growing middle class neighborhood in a southern area of Oceanside. Enrollment has increased 10.5% over the last year from 540 to 597. The school employs 21 faculty members with an approximate class size of 30 students each.

Ms. Whooley was the G.A.T.E. (Gifted and Talented Education) teacher for the 5 and 6 grades of the entire Oceanside district. Since G.A.T.E. was a district wide program, students were bussed in from other areas. Students were selected for placement on the basis of standardized test scores. If there were slots left over, they were filled with promising Garrison students and if at a later time new G.A.T.E. students were admitted, these students were supposed to be removed from the program. Ms. Whooley did not want to bump the Garrison students when this occurred so she had a class of 33 students.

The Daily Schedule. The school day began at 8:30 with a "class meeting." In the beginning of the school year, Ms. Whooley used this time to introduce the students to the expectations and routines of the classroom. As students became more adept at coordinating their own actions, Ms. Whooley used this time to discuss topics of current interest to the class as a unit.

The class meeting lasted approximately 30 minutes. This activity was followed by an hour of math instruction. After a twenty minute break for recess, there were three periods of language arts instruction. When the recess bell rang, the students were led back to the classroom from the playground by their teacher in a single line not differentiated by gender, age or grade level. Upon entering the classroom, the students went immediately to a predesignated location and were generally settled by 10:35 which is the official beginning time for the first segment of language arts. The hour and forty minutes of language arts time was divided into four 25 minute periods. The teacher generally went to her predesignated location giving little or no instruction at this point.

The Organization of Language Arts Instruction. During each language arts period, a group of students was assigned to one of four activities: Reading Group, Writing, Seatwork, and Centers. Reading Groups worked during periods one and three and were therefore doubled up; that is, two groups worked together during a single period. Students formed a "reading group" with the teacher at the front of the class. While the official district reading program was the Ginn series, this teacher virtually replaced the Ginn reading program with one called "My Favorite Author." The class was divided into two groups; each group was assigned a novel to read. The teacher emphasized silent reading and reading for comprehension in this program. The teacher felt strongly that students should read complete works--stories, poems, books, rather than isolated segments.

A typical reading group was divided into phases. In the first phase, the students were asked general questions about their experiences with a topic that had been read or will be read in the next segment. The students were encouraged to offer personal opinions, interpretations, and provide answers that diverged from any previous one. The teacher insisted that one student speak at a time, but access to the floor was voluntary--obtained by bidding or by nominations from the teacher. After a round or two of general discussion, the teacher oriented the students to the work they have been reading. The discussion turned to a link between personal experience and the events and activities being described in the book being read. Very little actual reading took place at the reading circle. Reading was assigned for seat work and for homework. When reading was done in the reading group, it was often to validate a point about the text or to support an interpretation being made about the text.

Writing and Seatwork. Writing and seatwork were both done at the student's personal desk. The writing activity for the day was written on the chalkboard. The general pattern involved students generating text based on topics provided by the teacher. Seatwork was a time for students to complete assignments, read assigned books, or library books, and do homework. Students were expected to work quietly and independently at their seats.

Centers. Center activity had another inner circle of organization. There were four centers at different locations along the edge or corner of the room. Each center had a unique activity associated with it. Center one started out as a typing center where students practiced specific typing tasks, and became a computer center. Center Two served a number of purposes: puppet plays, story recording, strategic games and library. Center Three was an art center for most of the year, although the form of art changed every week. The art form was often connected to a language activity by requiring a writing assignment about the art work at a later time. Center Four has been a listening center in which students listen to a story on tape while reading along in a book, and a map making center which also involves listening to a tape. Students at this center listen to map information on a tape while filling in worksheets on map reading (see Figure 5).

There were eight students in each color group and eight students assigned to center work during each period. This means that there were two students at each center during each period. The scheme for determining which students went to which center each period each day is done in two steps. First, was students determine when they would go to centers by looking at the four-by-four matrix already mentioned. If a student observed that his or her color group was assigned to centers for the current period, he or she then referred to a four-by-eight matrix chart. The horizontal axis contained the four centers identified by number, and the vertical axis listed the names of the eight students in that color group--there was a different chart for each group. The student found his or her name and looked across to where a thumbtack has been inserted to indicate the center to which they were assigned. The thumbtacks were changed every day by the teacher. Each student spent one period a week at each center and generally received a new partner each time. In practice, it was only the researcher who had to continually refer to these charts; the students always seemed to know where they should be (see Figure 6).

The end of each period is signified by the ringing of a small hand bell by the teacher. When the bell rings, the students move automatically to their next assigned location.

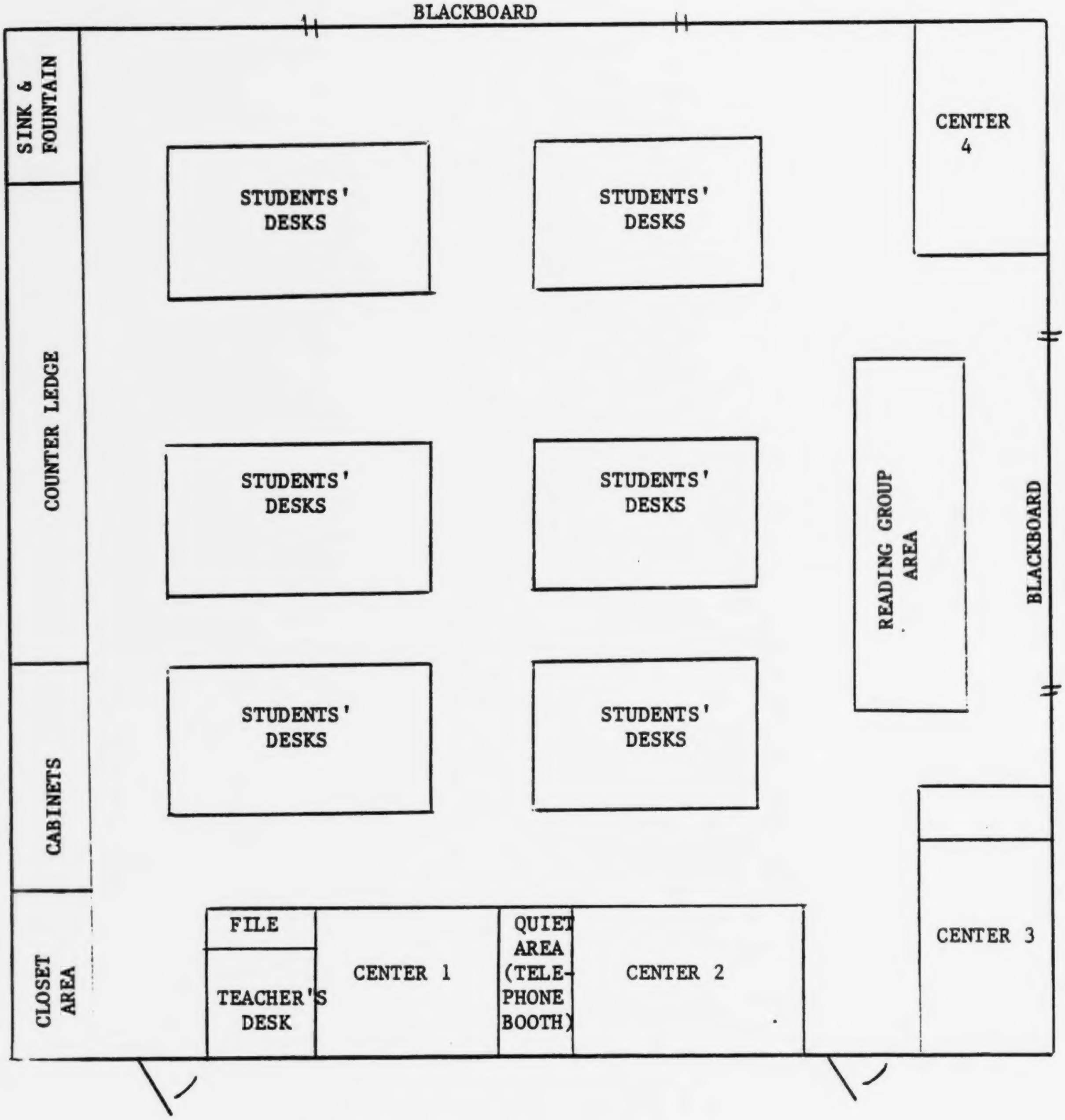
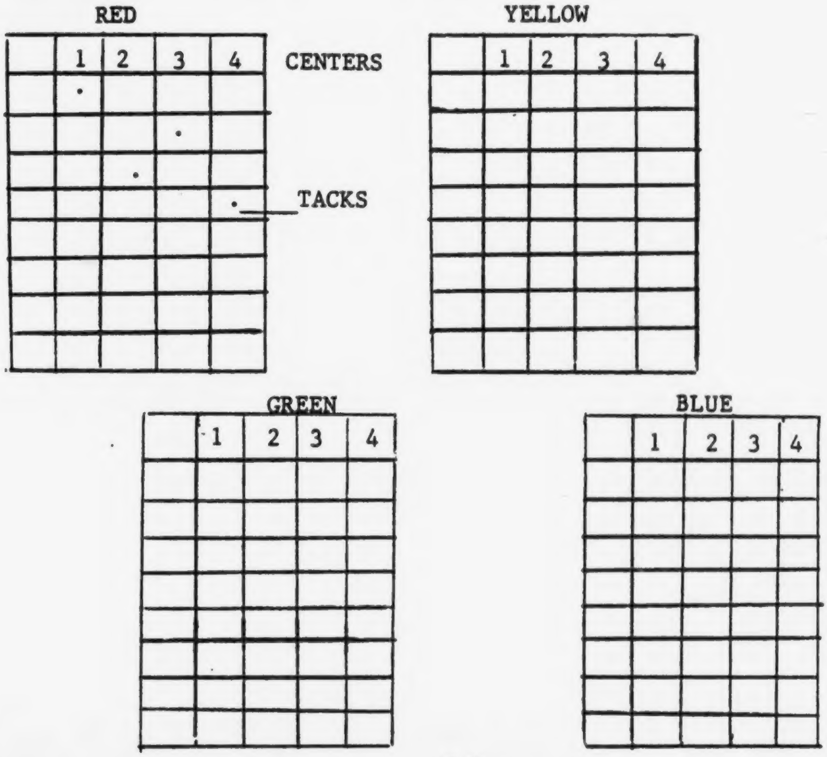

BLACKBOARD
SINK & FOUNTAIN
COUNTER LEDGE
CABINETS
CLOSET AREA
STUDENTS' DESKS
STUDENTS' DESKS
STUDENTS' DESKS
STUDENTS' DESKS
STUDENTS' DESKS
STUDENTS' DESKS
CENTER 4
READING GROUP AREA
BLACKBOARD
CENTER 3
FILE
TEACHER'S DESK
CENTER 1
QUIET AREA (TELE-PHONE BOOTH)
CENTER 2

FIGURE 5
GARRISON SCHOOL: 5-6 Grade

FIGURE 6: MATRIX CHARTS

	10:00-11:00	11:00-11:25	11:25-11:50	11:50-12:15
RED	GROUP	SEATWORK	CENTERS	WRITING
YELLOW	GROUP	WRITING	SEATWORK	CENTERS
GREEN	SEATWORK	CENTERS	GROUP	WRITING
BLUE	CENTERS	WRITING	GROUP	SEATWORK


RED
1
2
3
4
CENTERS
TACKS
YELLOW
1
2
3
4
GREEN
1
2
3
4
BLUE
1
2
3
4

The establishment of these practices in which the students had major responsibility for the organization of their learning was a significant goal for this teacher from the beginning of the year. She often commented to Drale and Mehan that she thought the students needed less academic instruction and more instruction about adopting individual responsibility. While it was the case that the rotation between groups and centers was smooth and seldom overtly directed by the teacher, considerable effort was expended in establishing these routines during the first few weeks of the year. The teacher did not start centers and small group instruction from the first day of class. She started with whole group instruction, emphasizing the need for individual student responsibility. After two weeks of coaching the students about seeking their own answers to questions, not seeking approval or sanction from her for each action, not asking her for validation or instructions, she introduced them to the centers and groups.

The introduction was accomplished in a fashion analogous to a stage rehearsal. The teacher literally walked the students through the group rotation, showing them where each group was to be at various times. For a week following the introduction of groups and centers, the students were given explicit verbal instructions at rotations. From that point on, the rotations took place without explicit verbal instruction. The students internalized the routine and followed it automatically. If the transition was particularly slow or noisy, the teacher added verbal cues or instructions. But from October 18, it occurred smoothly and quickly with students getting settled in less than a minute. During second and fourth period when the reading group was not meeting, three quarters of the students were at their seats. During this time, the teacher moved around the room monitoring activity both at the centers and at individual desks.

Summary. Kim Whooley maintained a firm yet flexible pedagogical framework. It was firm in the sense that she insisted on certain procedural criteria, like following directions, but flexible in terms of the students' creative input. One of Ms. Whooley's highest priorities was to encourage students to assume responsibility for actions which were within their capabilities. She flatly refused to "spoon-feed" her students, forcing them to be aware of and use alternative sources of information like dictionaries, instruction sheets and other students, etc.

In addition to being encouraged to take responsibility for their learning, students were also encouraged to take responsibility for their creative expression. Ms. Whooley was very reluctant to prescribe ideas in any creative endeavor. If a student solicited her approval of an already formulated idea, she gave it, but if the student wanted to be given an idea or to have Ms. Whooley select an idea out of several possibilities, she would not do it.

Cooperation was also an important theme in this classroom. Not only the traditional requirement of teacher-student cooperation, but also cooperation between students. In some cases cooperation was an explicit part of an activity such as working at the computer center where a pair of students had to help each other accomplish a common task. In other cases, it is implicit in an activity such as when a student had to attain missed or forgotten information from someone other than the teacher. Students were expected to give help to anyone who asked for it.

These themes were combined with a very explicit spatial and temporal organization. With the exception of the students' personal desks, which they rearranged every month, the rest of the room was well defined and consistent. Centers and resource areas did not move. The time divisions were clear with a physical signifier at each transition, either a verbal cue or a hand bell. Each time period had a specific organization, but not necessarily a single lesson content.

CHAPTER 3

MICROCOMPUTERS AND CLASSROOM ORGANIZATION: SOME MUTUAL INFLUENCES

Hugh Mehan

We are constantly being told that we are in the midst of a computer revolution. The computer is said to be the cause of changes in the organization of work, social relations, education, even the meaning of citizenship. Since microcomputers are becoming so pervasive in schools, it seems appropriate to look at the impact of microcomputers on the social organization of the classroom. We are interested to know whether the availability of microcomputers in classrooms has an influence on (a) the arrangement of the classroom and (b) the curriculum. That is, do teachers use time and space differently and make modifications in what they teach and how they teach as a result of having a microcomputer available for instruction.

The extent of the project teachers' knowledge about microcomputers and the manner in which they arranged their classrooms for instruction provided us with an opportunity to examine the impact of microcomputers on classroom organization. All four of the teachers in this project were expert teachers. But not all four were expert concerning the use of microcomputers. Two of the teachers, BL and KW, had not previously used a microcomputer on a regular basis, or had formal training in computer programming or computer use. Two of the teachers, BMS and RR, had extensive experience using microcomputers but had not had them available for full time classroom use prior to this project. BMS had access to an Apple // for her classroom on a part time basis during the previous academic year, voluntarily led after school computer clubs and had taught classes on word processing through a university extension program. RR was in his third year of regular computer use. After using computers for math and language arts instruction in his classroom on a part time basis, he now had the additional responsibiliy for leading his school's computer lab. This project made a microcomputer available to him to use full time within his classroom.

At the beginning of the school year, that is, before microcomputers were introduced into the classrooms, there were two main systems of organizing classrooms for instruction. BL and RR used "whole group" arrangements as the primary mode of delivering instruction. BMS and KW used "learning centers" as the primary mode of delivering instruction.

The relationships among teacher's previous knowledge about computers and the manner in which they arranged their classrooms at the begining of the school year are shown below:

Figure 7

Teachers' Previous Knowledge about Computers

	Expert	Novice
Whole Group	RR	BL
Classroom Arrangements		
Centers	BMS	KW

We will discuss the relationship between microcomputer use and classroom organization under two headings: (1) the impact on temporal and spatial arrangements and (2) curriculum--what teachers teach and how they teach it. After our treatment of these topics in this chapter, we will discuss BL's classroom in greater length in Chapter 7, because of the unique combination of changes that took place there.

We are trading off the convergence of ideas from two quite different theoretical approaches to organize our observations. One of these theoretical approaches is called the study of "activity structures" and is associated with Bossert (1977) and Doyle (1978). The other is called the study of "participant" or "participation" structures," which was developed by Philips (1972; see also 1982), and has been used by Mehan (1979), Erickson and Mohatt (1982) Dorr-Bremme (1982), Florio (1978), Au (1980), and Moll and Diaz (1984).

Both approaches suggest that classroom activities can be described along a number of dimensions. These include (1) the size and the organization of the work group, e.g., whether the class is organized into one learning unit ("whole group" instruction) or is broken down into small groups or is organized so that the teacher works with students on a one-to-one basis; (2) the *task organization* in the classroom (e.g., whether the whole class is working on a single task or small groups are working on many tasks simultaneously); (3) the *response opportunities* available to students in a recitation (e.g,, whether students respond individually or in a chorus); (4) the *response obligations* (e.g., whether students are allowed to respond voluntarily or responses are obligatory); and (5) *evaluation* (e.g., whether evaluation of work is conducted in private or in public).

These dimensions of classroom life orient our description of the relationship between microcomputer use and classroom organization as well as our comparision of the structure of instruction when computers are used and instruction when computers are not used.

Impact on Spatial and Temporal Arrangements

There was no significant change in the way in which the teachers, BL, BMS, RR and KW arranged the space and used time in their classrooms as a result of having a microcomputer available for instruction on a full time basis. Both BMS and KW had used learning centers extensively in previous years. Both teachers used this spatial and instructional configuration when a microcomputer was made available to them by this project. BL and RR had used whole group methods of instruction in previous years; they continued to teach their classses in this manner when this project made a microcomputer available for their use.

The Inclusion of the Microcomputer into Existing Classrooms

Arrangements. BMS and KW injected the microcomputer into their on-going learning center arrangements. KW established a "computer learning center to complement her Art Center, Science Center, Map Center and her Listening Center. Students rotated between these centers, a teacher-led reading group and individualized seat work during the course of a morning's language arts work (see Chapter 2 for more details). In a similar manner, BMS used the microcomputer to complement her previously established methods of instructing reading and writing. BMS taught Language Arts to small groups within the framework of three activity centers (called "stations"). Three language arts ability groups rotated through the three centers four days a week. One station was devoted to reading comprehension activities, another was dedicated to reading in content areas such as Science or Social Studies, and the third to a variety of individualized activities. The computer was made a part of the third station and was used to enahnce a number of activities taught in other parts of the Language Arts framework.

The structure of participation in both BMS's and KW's classroom varied with the activity being conducted. "Group work," in which students carried out teacher organized activities without direct adult supervision, was characterized by voluntary, student initiated participation. "Reading Group," in which students read and discussed texts, was more teacher directed. In a typical reading group, students were first asked questions about their experiences with a topic that had been read or would be read in the next assignment. THe students were encouraged to offer personal opinions, interpretations and provide answers that diverge from previous answers. The teacher insisted that one student speak at a time, but access to the floor was voluntary. The floor was obtained by bidding or by nominations from the teacher. After a round or two of general discussion, the teacher oriented the students to the work they had been reading. The discussion turned to a link between personal experiences and the events and activities being discussed in the book being read. Very little actual reading took place at the reading circle. Reading was assigned as seat work and for homework. When reading was done in the reading group, it was often to validate a point of interpretation being made about the text. "Writing" and "seatwork" were both done at the student's personal desk. The general pattern for the writing activity involved students generating text based on topics provided by the teacher. Seatwork was a time for students to complete assignments, read books from the reading group or do homework. During these times, students worked without supervision, at their own pace.

RR taught his class as a whole group followed by discussions and then seat work with students working alone or in small groups. The typical pattern of instruction was for RR to present material to the whole class and then engage students in a discussion. Students worked on the lesson activities after the large group presentation. During these work periods, the teacher and his aide assisted students by answering questions privately and by giving encouragement. RR placed the microcomputer against one of the classroom walls. Pairs of students were scheduled at the computer in 25 minute intervals throughout the morning. As each pair's turn came, they left the work they were doing and went to the computer.

BL responded to the availability of a microcomputer for classroom instruction in much the way that RR did. She arranged the students' desks into rows and primarily instructed her students as a group while they were seated at their desks. She established a computer center against one of the classroom walls. At first situated by the door, she moved it to a location closer to her desk after 6 or 7 weeks of use so that she could monitor students' activities at the computer more effectively. The computer was partially hidden and isolated from the rest of the classroom by a divider, which also served as a display board for the computer users, containing disks, instructions and other relevent information. From her usual position at the front of the class, BL had a clear view of the children working at the computer and in other parts of the room. The children were assigned in pairs to use the machine for 30 minute intervals. Each Monday morning BL described the computer activity for the week, her expectations for their work and provided examples of the procedures they were to follow.

The manner in which the teachers set up computer center in their classrooms had consequences for students'learning. The teachers who used learning centers rotated all students through the computer center which meant that they were not removed from other classroom activities. The teachers who used "whole group" instruction, however, removed students from other activities to work at the computer center. As a consequence, they had to have students make up for the course work they missed while they were at the computer center. Rowe's solution to the problem was to make it clear to the students that it was their responsibility to make up for the work they missed while working at the computer. Liner used an elaborate schedule to provide students with opportunities to make up for missed work.

The Addition of a New Dimension of Participation: Dyadic Peer Interaction. While the introduction of a microcomputer for the purposes of instruction did not modify existing spatial and temporal arrangements in the four project classrooms, the availability of a microcomputer added a new dimension of participation to the classrooms. Each of the teachers in this project decided to have two students work at the computer at one time. The teachers made these decisions for pragmatic and pedagogic reasons. Two students working at a computer increases, perhaps doubles, the total access time that a student has to the computer. Since each of the teachers in this project had 30 or more students and one computer, the logistics of organizing instruction limited the number and length of work sessions. By placing two students at the computer at one time, our teachers found that they could provide students with two 25-30 minute sessions a week, one devoted to math and one devoted to language arts.

Dyadic peer interaction was the new structure of participation that emerged when two students were placed together to work at the computer. Students were given assignments for work sessions at the computer by the teacher, either verbally at a whole-group orienting session, or in writing at the computer center itself. Students worked together at the computer center. The teachers posted numerous sets of instructions around the computer. The first set gave students instructions with basic "boot up" activities. Supplementary instructions were added to give more specific instructions about each week's activities. Students worked together on the assigned activity carrying out the teacher's assignments without direct adult supervision. When they had difficulty with computer operations, they often called to the teacher for help. However, the teachers' response was to encourage the students to use each other as resources, consult the written instructions around the computer, or to go to other students for assistance.

The teachers did not dictate a particular form of interaction to the student pairs. They were left to their own devices to sort out the manner in which the task would be completed. In that sense, the students' participation in the computer activity was voluntary, not compulsory. While they were responsible for completing their assigned session at the computer, the details of how that session would be completed was left to the students. Since the teacher did not monitor the students at the computer directly, their work was not evaluated moment-to-moment or publically, as it so often is in regular classroom lessons (Mehan, 1979).

Although the teachers did not monitor the students' work at the computer directly, incidental teacher evaluation was almost always present. As part of their regular travels around the classroom, teachers passed by the computer center. They often stopped and checked on students' work, offerred suggestions, or were called upon by the students for help. Students working at the computer also called upon other students for help. These students gave instructions, and in the process, commented on students' work (see Chapter 5 for a more extended discussion of students' use of social resources at the computer center).

As a consequence of this additional participation structure, students developed a different sense of social relations. The students assisted each other at the computer in ways that were different from their experiences in other parts of the schedule. They often corrected each other's mistakes and cooperated in the completion of assigned tasks. Another consequence of dyadic peer interaction was that it provided social resources which facilitated learning. In language arts activities, even when neither student began an assignment with an idea of what to do, the discussion of the problem often presented the students with the way to proceed. In the process of entering text, the student who was typing was often concerned with such local issues as the spelling of a word, while the other student concentrated on more global issues such as the construction of the essay and coherence among sentences. We will discuss the cognitive consequences of peer interaction in more detail in the next chapter.

Impact on Curriculum

BMS, RR and KW entered the project approaching Language Arts instruction from a perspective that integrates the teaching of reading with the teaching of writing. By emphasizing the writing process (Cooper and Odell, 1978), these teachers used the text that students wrote to create opportunities for students to read. In turn, texts that students wrote became a basis for later reading.

The computers were thoroughly incorporated into the instructional plan of the language arts curriculum. The teachers planned for computer activities in the same manner that they planned for other instructional activities. The computer was used in all phases of the writing process--pre-writing, writing, response, revision, evaluation and post writing. The computer was not an isolated piece of educational technology that students were taught about. It was a functioning part of the classroom environment and was used as frequently and in the same way as tables, chairs, typewriters, tape recorders, paper, pencils, chalk and chalkboard.

The Computer as a New Means to Meet Previously Established Curricular Ends. The teachers organized tasks for the microcomputer that were coordinated with tasks that were carried out in other parts of the curriculum. Reading and writing activities that were taught using paper, pencils and chalkboards were coordinated with activities that were taught using the microcomputer. For example, a poetry writing activity begun with paper and pencil was extended to the computer center where a similar writing activity took place. In this role in the language arts curriculum, the microcomputer was a means to meet previously established educational goals. As we will discuss in detail later in this report (see Chapter 6), students writing using the word processing systems that are available on microcomputers facilitated the development of the students' control over the reading and writing processes. This improvement seems to have occurred, in part, because the screen editing and printing capabilities of microcomputer systems improved the production of students' texts by subordinating the mechanical details of writing (such as producing neat script, spelling and correcting errors) to the higher order goals of clear writing, fluency and the flow of ideas.

This statement should not be interpreted as a claim that word processors are responsible for improved writing, however. The computer by itself is not an agent of change. In and of themselves, word processing systems can not teach children to read and write. While we have found that word processing systems can not transform unskilled writers into skilled ones, they do have properties that enable teachers to make a new social organization for reading and writing possible. It is this social organization and not the microcomputer that changed both what was taught and the way in which it was taught in the project classrooms.

Language arts instruction was organized with a microcomputer to establish "functional learning environments" (LCHC, 1982; Riel, 1983; Levin, 1982; Newman, 1984), i.e., those in which reading and writing are organized for communicative purposes. It is at this juncture that the microcomputer moves beyond its role of providing a new albeit dynamic means to reach previously established goals, to providing a medium through which new and previously unattainable educational goals can be reached.

The Computer as a Means to Meet New Curricular Goals. We extended the work of Riel (1983) and Levin et al. (1984) by establishing functional learning environments using the student newswire service known as the "Computer Chronicles" in the project classrooms. The Computer Chronicles Newswire is a network that currently connects students from Alaska, California, Hawaii and Mexico. Students from each of these locations write and edit articles stored on floppy disks. The disks are sent to all sites participating in the network. Students at each site use the articles they have written as well as ones written by students in the network to produce their local editions of the Computer Chronicles newspaper. The network was explicitly modelled on the international news wire services. Whenever possible, students' attention is focused on the parallels between their work and the work of newspaper editors and reporters.

The Computer Chronicles helped the teachers establish learning environments that were functional, i.e., reading and writing were organized for communicative purposes and not just as an exercise for teachers to evaluate. The presence of an audience for writing, in the form of classmates, parents and peers in Hawaii, Mexico and Alaska, was a crucial ingredient in making the Computer Chronicles a functional system for reading and writing. Having an audience with which students were unable to communicate verbally, but with which they wanted to share ideas, gave students a purpose for writing. This writing for a purpose and not "just writing" or even writing on the computer, subordinated students concern for the mechanics of writing to the goal of communicating clearly (see Chapter 6 for a more extensive discussion of changes in students' writing as a consequence of participating in these functional learning environments).

When the students realized that other people would read their work for the information they provided and not just to evaluate its form, they took control of their writing. They engaged actively in revising and editing their own writing and the texts of their peers. After students wrote and edited their articles for the Newswire, the articles were submitted to a local editorial board for consideration. If the local editorial board, composed of five to eight students, accepted the article, then it appeared in the classroom newspaper and was read by the author's family and friends. Articles were also sent over the newsire to other schools, where other students reviewed their work and decided whether to include it in their local newspapers. If accepted in these remote locations, then not only local peers, but people in Alaska, Hawaii and Mexico read the work. This goal of writing for an audience was extremely effective in motivating both reading and writing.

Summary and Conclusions

In this chapter, we have considered whether the availability of a microcomputer for day-to-day instruction in classrooms affects the way in which teachers arrange their classrooms, and modifies what teachers teach and how they teach.

While there is no doubt that there are widespread changes associated with the microcomputer in the world of work and education, our research in the classroom suggests that it would be inappropriate to conclude that the computer, in and of itself, is a causal agent of change. When used in educational settings, the microcomputer is always a part of a larger social system, which includes the students, the teacher, their history of past relationships, the history of ways of teaching, the history of ways of organizing classrooms, the relationship that the classroom curriculum has to to the classroom surroundings, and the relationship between the classroom and the school, community and agencies beyond.

There was no significant change in the way in which the teachers arranged the space and used time in their classrooms as a result of having microcomputers available for instruction on a full time basis. The microcomputer was incorporated into previously established practices for organizing instruction. Teachers who used learning centers previously did so again when microcomputers became available. Teachers who typically taught their classrooms as a whole followed by discussions and individual seat work continued to do so when they had microcomputers. This pattern was the same regardless of the teachers' previous knowledge about computers.

The absence of changes in temporal and spatial arrangements that we observed when microcomputers were introduced into classrooms shows how resilient that classrooms are to attempts to change (Sarason, 1982; Cuban, 1983). If the results of our modest investigation are replicated in other school settings, then we would not be surprised if microcomputers continue to be inserted into existing classroom arrangements (Michaels, 1984) and do not lead to wholesale changes in classroom organization.

While the introduction of a microcomputer did not modify existing spatial and temporal arrangements, the availability of a microcomputer added a new participation structure to the classroom. Teachers placed two students together at the computer. Peer interaction emerged from this arrangement. Students worked together at the computer without direct adult supervision. They were left to their own devices to sort out the manner in which tasks would be completed. While students were responsible for completing their assigned work at the computer, the students worked out the details of task completion themselves, resulting in voluntary not compulsary forms of instructional activity. Since the teachers did not monitor the students' work at the computer directly, their work was evaluated privately not publically by the teacher. As a consequence of this change in participation structures, students developed a different sense of social relations. They assisted each other at the computer and cooperated in the completion of assigned tasks.

Microcomputers also had an impact on the curriculum in these classrooms. They served as a means to meet previously established educational goals, and they provided a means through which previously unattainable goals could be reached. The teachers used the microcomputers to create functional learning environments in which reading and writing was arranged for communicative purposes. The "Computer Chronicles Newswire" gave students a reason for writing: to share ideas and concerns with other students with whom direct interaction is not possible. The public nature of writing provided motivation for re-writing and editing, giving students increased knowledge of educational technology.

The teachers' connection to the student newswire service enabled them to achieve important educational goals, goals that they could not have achieved as readily had a microcomputer not been available for their use. Students from different countries were able to interact via microcomputers and telephone lines and participate in joint problem solving activities centered on instructional issues. As a component in a unique electronic communication system, the microcomputer has the potential to help teachers address important curricular objectives. While students are developing their skill in using the computer for word processing, they are being placed in contact with students from different cultural backgrounds. In the context of gaining experience in communicating across cultural and linguistic boundaries, teachers and students are provided with the opportunity to gain understanding of the norms and traditions of different cultures and to thereby increase understandings of their own cultural norms and traditions.

In short, the microcomputer was accommodated into existing classroom organizational arrangements, but was associated with changes in teacher-student relations and curriculum. Therefore, we are led to dismiss accounts which say that classroom culture will dictate the organization of classroom computer use and to dismiss accounts which say that the availability of microcomputers will cause wholesale changes in education. At this point in our investigations, we are more inclined to adopt an account that characterizes the relationship between classroom organization and computer use as a mutually influential one.

CHAPTER 4

SOME COGNITIVE AND SOCIAL BENEFITS OF PEER INTERACTION ON COMPUTERS

Hugh Mehan, Nick Maroules and Christina Drale

For the reasons we described in Chapter 3, each of the teachers in our study decided to have two students work at the computer at one time. The teachers' decision to place two students rather than one student at the computer enables us to ask the following question about computers in classrooms:

> Do students working together receive cognitive and social benefits from their interactions?

The cognitive issues that arise from peer configurations at the computer concern the relationship between learning in social situations and learning in individual situations. Simply stated: are social learning situations productive? Do pairs of students working together get their work done, or does their attention get diverted from assignments?

While there have not been many studies that directly compare learning in group vs individual situations at a computer (the exception is (Trowbridge and Durnin, 1984), there are studies which suggest that there may be benefits which accrue to students working together that do not accrue to students working alone in studies of peer learning. Vygotsky (1978) discusses learning situations in which more knowledgeable people assist less knowledgeable people until the less capable are able to take over the task. In this way of thinking, knowledge proceeds from the social to the psychological, as individual learners internalize the teachings from representatives of the larger society.

Observers of students teaching students (Steinberg and Cazden, 1979; Mehan and Riel, 1981; Riel, 1982) find that peers make suggestions, model and demonstrate activities to each other. Studies of "cooperative learning" situations (Webb, 1982; Slavin, 1983; Kagan, 1984) [in which a classroom of students is divided into small teams whose members are interdependent] show students improve in academic achievement, interethnic relations and pro-social development. These gains are especially prevalent among sociocultural minorities.

Verbal interaction is a potentially important mechanism in these situations, because students working together talk out loud to each other. The act of verbalizing material is thought to lead to cognitive restructuring on the part of the students who are attempting to explain. Verbal interaction is also important because it leads students to hear different points of view, which, in turn, can lead to cognitive conflicts. Cognitive conflicts are important, it has been argued, because it forces learners to examine their own understanding, and to seek resolutions of conflicting viewpoints (Piaget, 1971).

Background Information

Before assessing whether there are cognitive and social benefits of peer interaction at the computer, we will provide some background information about the organization of a work session at the computer and the design of the software employed by the teachers.

The Phases of a Computer Work Session

A given work session at the computer can be thought of as a "lesson" because it has many of the elements of classroom lessons described previously (Mehan, 1979; Shuy and Griffin, 1978; Erickson, Schultz and Florio, 1982). One of the points of similarity which is important for our purposes concerns the sequential organization of the work activity. A work session at the computer has three "phases": "a start up" phase, an "academic" phase, and a "wrap up" phase.

The start up phase is concerned with initial machine operations. Students select a disk from the library of discs available to them near the computer, insert a disk into the disc drive, turn on the machine, move disks around, call up the menu, select the program from the menu. The nominal academic phase places the students in interaction with the program selected. We say "nominal" academic task here because previous research (e.g., Hood, Cole, and McDermott; Mehan, 1980; Riel, 1982; LCHC, 1982) has pointed out time and time again that students' definitions of situations do not necessarily match teachers' definitions of situations. As a result, we make the principle of multiple definitions of situations an operating tenet of our research. The wrap up phase is the mirror image of the start up phase. Students leave and update their program, print their work, remove disks and return them to the library, turn off the machine, and leave the work station.

Software Design

The software that our teachers used for language arts can be placed along a continuum from those that provide a great deal of support for composing text to those that provide very little support. The computer does most of the work at the supportive end of the continuum, and students must do most of the work at the minimal support end.

Static Frames with Fixed Content	Lesson Frames with Content Added	Open Frames with Variable Content
<-------------------	-------------------	------------------->
Program Controlled	Mixed Control	User Control

Figure 8: A Continuum of Educational Software (from Riel et al., 1984)

The prompts at the most supportive end of the continuum are program controlled. They are organized as static frames with content that does not vary. Information appears as fixed choices, analogous to multiple choice questions. Students produce a text by selecting between alternative wording in the texts and by choosing different branches or story episodes. The prompts of the software at the next step on the continuum provide a mixture of control between program and user. Students are asked to fill in words and phrases as well as make choices among predetermined options. As students increase their writing skills, more and more of the writing activity is taken over by the students. The next phase shifts control from the program to the user by having students work within open frames in which the content of students' work can be varied. Students enter their own sentences in response to specific prompts.

Finally, students produce complete texts on their own.

This continuum of support will be illustrated by reference to a set of interactive texts called "the Expository Prompt." Developed by one of the teachers in our study (Miller-Souviney, 1985), this software was used by the teachers in our project in sequence from program control to user control.

Here is an example of the Expository Tool at the program control end of the continuum. Students choose among fixed options presented by the computer program when creating an essay about making a sandwich:

SANDWICH PROMPT

```
Today is

1.  Saturday

2.  Martin Luther King Jr.'s Birthday

3.  Teacher's Workshop Day

4.  National Take a Computer to Lunch Day

    (Choose 1...4; 0 to exit);
    (Type a number then push return)

and I have a day off from school.

My parents are

1.  at work

2.  climbing Mount Everest

3.  eating at a restaurant

4.  playing tennis

    (Choose 1...4; 0 to exit);
```

```
        (type a number then push return)

    so I have to make my own

    1.  breakfast

    2.  lunch

    3.  dinner

    4.  snack

        (Choose 1...4; 0 to exit);
        (type a number then push return)

                   (etc.)
```

After students gained familiarity with choosing among fixed options, the teachers moved to the next phase on the continuum. Here is an example of a mixed control program. Students add the content to the frames provided by the program to make a story about a "School Day Schedule":

SCHOOL DAY SCHEDULE PROMPT

```
The name of my school is

      ?

      (Type, then push CTRL-C when done)

It is in the town of

      ?

      (Type, then push CTRL-C when done)

I am in grade

      ?

      (Type, then push CTRL-C when done)

and my teacher's name is

      ?
```

(Type, then push CTRL-C when done)

I have a very busy schedule at school. My class does all sorts of things to make it fun to learn.

(etc.)

This "School Day Schedule" prompt provides students with the beginnings of sentences and paragraphs and invites students to complete the ideas begun for them by the expository prompter.

As the students increase their writing skills, the teachers moved them further along the continuum toward user control. In the third expository writing task, the students are presented with the topic of "how to run a computer." Topic sentences for each paragraph as well as reminders of what is contained in each paragraph are provided. Students enter their own sentences which become the introduction, body, and conclusion of their essay.

HOW TO RUN AN APPLE COMPUTER

We are lucky here at Olive School. We have Apple computers. We use them to help us practice our spelling and math, write stories and lots of other things. An Apple computer is easy to run. Just follow these simple directions.

First, it is important to know the different parts of the computer and what each does.

(Write complete sentences telling the parts of an Apple and what they do.)

?

(Type, then push CTRL-C when done.)

Next, to start the Apple, several switches need to be turned on.

(In complete sentences, describe where each switch is and what it does.)

```
?

(Type, then push CTRL-C when done.)
etc.
```

In the final activity in the expository writing series, students are presented with "How to..." topics to write about, but little in the way of supporting instructions. Students are now responsible for producing complete texts on their own.

HOW TO PROMPTER

Think of something you know how to do that you could explain to a friend about. For example, you may know how to wash dishes, run a computer or clean your room.

Remember:

1) The first paragraph is your introduction and will tell something about the activity.
2) The second paragraph will tell the steps it takes to do it.
3) The last paragraph is your conclusion and can tell about how you feel when you finish the activity or when you will do it again.

Throughout these activities, the educational goal is for the quality of the writing to remain constant while the degree of the participation of the learner increases, concomitant with a decrease in the degree of support provided the computer.

The Division of Labor in Computer Operations

The circumstances at the computer center are complex. An academic task is presented to the students, the goal or end point of which is specified (e. g., edit a letter, write an expository essay), but the means to reach that goal and the manner of completing the task are not specified by the teacher. Faced with the challenge of figuring out how to carrying out the teachers instructions, it was possible that one student would dominate the encounter and perform the entire task alone while the other student watched passively and helplessly. We did not find this kind of imbalance, however. Like Levin, Boruta and Vasconcellos (1983) before us, we found that the students cooperated to complete the tasks at the computer. We did not observe any work sessions in which one member of a pair performed all operations and the second member of the pair did nothing. Thus, a division of labor is one consequence of placing two students together at a computer for the purpose of accomplishing academic tasks.

Diversity in the Division of Labor

While students divided up the assigned task in each and every computer work session, they did not divide the task in the same way upon every occasion. The procedures that the students used to divide up the task ranged from those which had a sequential quality to those that had a parallel quality.

Sequential Processing. Sequential processing occurred when students divided up the task into units and took turns, each student performing all the actions necessary to complete that unit. Once a student had completed his or her turn, s/he turned the keyboard over to the other student.

The turn units varied in size. The smallest unit was a single key stroke e.g., entering a letter or a number in response to a prompt from a "forced choice" computer program, or pushing a return key. Turn units of intermediate size included a sequence of key stroke-return key combinations or a string of text. The largest turn unit was a complete text. When writing a complete composition, a student made all the choices necessary to complete a poem or a story in response to prompts from the computer program (e.g., Sandwich Prompt, Science Fiction Story or How To Run an Apple Computer).

The following example is representative of those in which the task is divided sequentially, i.e., one student completing a turn is followed by a second student completing a turn. In this example, the students have been asked to write a science fiction story. The software is at the "Program Control" end of the software continuum (see Figure 8), i.e., students make choices from a menu of selections presented to them on the monitor:

Example #1 [BMS classroom; Oct. 6, 1983; students writing
writing stories with "Science Fiction Story Maker"]

Turn	Ss	Action
1	M,S:	What is your name (reading from monitor)
2	S:	Me first (begins to type) / Ok first we'll do my name/ Return
3	M:	(presses return key) (makes selection, presses return key) / makes selection, presses return key)
4	S:	I get to do (makes selection) / Your turn
5	M:	(presses return key)
6	S:	(makes selection, presses return) / Your turn

7 M: (makes selection, presses return)

8 S: No

9 M: (makes selection, presses return) / (presses return)

(BMS 9; Oct. 6, 1983)

The first few exchanges between the students in this work session were characterized by considerable competition for a turn to respond to a prompt (see lines 1-4). There were also frequent shifts in the length and duration of a student's turn in interacting with the computer. Table 1, below, summarizes turn units and order for the turns in which students made entries during this work session.

Table 1

Summary of Turn Units and Order BMS9: First Story

Turn	Student	Unit
2	S	name
3	M	return key/selection key/ return key/selection key/ return key
4	S	selection key
5	M	return key
6	S	selection key/return key
7	M	selection key/return key/ selection key/return key/ return key
9	M	selection key/return key

While we have the "ab,ab" alternation which is so characteristic of naturally occurring conversations (Sacks et al., 1974) and classroom lessons (Mehan, 1979), we also have units varying in size from a single press of the return key (turn 4) to a sequence which involves multiple selections (turn 6). In addition to the variability in size and duration of turn units, the first stories that students wrote at the beginning of the school year were often characterized by considerable competition among participants in an effort to establish ownership of valued resources, e.g., the computer keyboard. Consider the following story written by A and B:

Example #2: [BMS' classroom; Oct. 4, 1983; Students were writing writing stories using "The Science Fiction Story Maker"]

Turn Ss Action

1. B: What is your name, what is your name?
2. A: (enters text)
3. B: (makes selection)
4. A: I get to do the next one, okay?
5. B: I get to pick though, I get to pick though
6. A: Uh uh. You do one and I do one
7. B: Okay, giant giant
8. A: (makes selection)
9. B: No tiny tiny / no wait. Okay, now I get to pick
10. A: No, you do this one
11. B:
12. A: Yeah okay, you do this one
13. B: (enters selection)
14. A: And I do the next one/ Return/ Now I get to do the next one
15. B:
16. A: (makes selection)

17. B: No

18. A: I get to pick, now you get to pick which one

19. B:

20. A: Go

21. B: (makes selection)

22. A: Now I get to pick the next one/ (makes selection)/ Now I'm going to pick two. Yesterday's was stinky.

23. B: (makes selection)

24. A: (makes selection)

25. B: No/ (makes selection)

26. A: (makes selection)

(BMS 3: Oct. 4, 1983)

In this sequence, A is vociferous in his attempts to allocate alternating turns every time the computer provides a prompt. We can see at least eight specific actions on A's part in this effort, (see lines 4, 6, 10, 12, 14, 18, 20 and 22), which suggests that students attached a high value to a limited resource--access to the computer keyboard.

By making selections from a menu, students were able to create between five and nine stories in a 25 minute working session. By the time students had created three stories together, they discarded small units (e.g., keystrokes) and negotiated the "story" as the turn-taking unit. The systematic nature of this shift from turn-units of small to large size became even more evident as students wrote more and more menu-driven stories together.

The systematic shift from small turn-units to large turn-units also illustrates the multiple definitions of the situation, which in turn, reinforces the need to talk about the academic task in nominal terms. While the teacher had defined the goal of the academic task in terms of students gaining practice with hard and software and producing complete stories with the aid of the computer, the students often saw this activity differently. For many, it became a session in which to produce as many and as silly stories as was possible. This alternative definition of the work session sometimes resulted in frantic key pressing and story printing.

Parallel Processing. Parallel processing occurs when students divide the task into actions such that one student is responsible for certain types of actions and the other student is responsible for other types of actions. In general, one student took responsibility for entering text, while the other student took responsibility for monitoring the text entry. The student who adopted the monitoring role made suggestions about story content and corrected mistakes in machine operations. This "in-process editing" of stories and poems included modifications of language mechanics such as spelling and grammar and those concerned with more global issues such as the overall organization of an essay and coherence among sentences.

The following exchange is an example of parallel processing in which student R does all the key entry while student S contributes in process editing:

Example #3: [KW's 5-6th grade classroom, Dec. 1, 1983; students were editing a letter previously written by the teacher using the Writer's Assistant Text Editing System]

Turn Ss Action

S: Do you think we should put a comma there?

R: I don't know. First of all we've got to drop the whole word.

S: Yeah.

R: Morning. ...Where's drop? Drop.

S: Then...

R: All right, we drop one more so that that gets erased, and then control-C.

S: And then you push in.

R: Input.

S: M-o-r...

R: Okay, m-o-r-n-i-n-g, good morning, and then...

S: Control-C

R: Um, no, I think we should put a, a what's it?

S: Exclamation?

R: Yeah, exclamation...

[KW #11, Dec. 1, 1983]

Notice that the task is no longer a series of turn units, but rather a single unit with shared responsibility. Student S asks, "Do you think we should put a comma there?" (turn #1). Student R answers "We've got to drop the whole word" (turn #2). This is very different than the "I" and "you" language in Examples 1 and 2. This pronominal usage marks the shift from single production to joint production in the students' work.

In the next exchange, the division of the task into two parallel processes is more pronounced as student X does all of the key entry while student Y suggests the content.

Example #4: [KW's classroom April 26, 1984, students were assigned to write a newspaper article using the Computer Chronicles Prompter]

Turn	Ss	Action
1.	Y:	What is this?
2.	X:	I don't know. [X does key entry] That scares me when it does that.)
3.	Y:	Okay, that's it.
4.	X:	Okay, let's think about this.
5.	Y:	Uhm, let's look at things to write about. [Y looks at posted list of things to write about] Uhm, I know.
6.	X:	What?
7.	Y:	Let's write about the book club...Tom Sawyer, Tom Sawyer?
8.	X:	Wait, wait, let me look at this ((pause)) okay, we'll write about the book club.
9.	Y:	What?
10.	X:	We'll write about the book club.
11.	Y:	Let's see what we've got...news.
12.	X:	Or would it be fun; no, news.
13.	Y:	News.
14.	X:	School news.
15.	Y:	School news.
16.	X:	Uhm, do we have a headline? ((pause)) Garrison book, Olympic book, Garrison salutes the Olympics, uhm Garrison book club?
17.	Y:	No, Garrison Olympic book club. Okay? Garrison Olympic book club. ((laughter)) I feel like I'm being wired. [referring to the video equipment]
18.	X:	((laughing)) I know. Okay, we do have one.
19.	Y:	Garrison Olympic book club. [X enters headline.]

20. X: I feel like your secretary kind of. ((laughs))

21. Y: [In an affected tone] Please type this, please send this letter in please.

22. X: I know, I love to type. ((pause))
--I'll do all the typing, I like to type.
¶

23. Y: --( ) right in my face. [referring to the video equipment]
It's kind of uncomfortable. ((pause))

24. X: Garrison...

25. Y: Garrison, I'll write it in.

26. X: Olympic book club.

27. Y: I know.

28. X: I'll type it all in.

29. Y: ((sigh)) (says name of partner)

30. X: B, b, okay. [X continues to do all key entry] And then shift.

[KW #19, April 26, 1984]

This example demonstrates the importance of role in parallel processing. Each student has different responsibilities throughout the entire task and any infringement of role responsibilities bring sanctions from the other student. The division of labor is not rigid, however. This example shows that students negotiate their roles and responsibilities; responsibility for the content of the story is shared even though student Y usually has the final say.

Later on in this work session, student Y takes on the role of in-process editor.

Example #5: [KW's classroom, April 26, 1984. Students were assigned to write a newspaper article using the Computer Chronicles Prompter]

Turn	Ss	Action
1.	X:	Garrison... [X is doing key entry]
2.	Y:	It's librarian, not liabrarian.
3.	X:	Okay.
4.	Y:	Oh no.
5.	X:	(I messed up) How do you spell librarian?
6.	Y:	I'll spell it. [Leans toward the keyboard]
7.	X:	No, no, I'll type it, you just tell me.
8.	Y:	L-i-b-r...
9.	X:	A-i-n.
10.	Y:	No, it's not.
11.	X:	It's i-a-n.
12.	Y:	No, it's r-a-r,
13.	X:	R-a-r [X enters letters as she says them]
14.	Y:	I-a-n.
15.	X:	I-a-n.
16.	Y:	That's better.
17.	Y:	Okay.

[KW #19 April 26, 1984]

Summary. A diversity in the division of labor is a second consequence of placing two students together during work sessions at the computer. Students divided up the task presented to them in a variety of ways, parallel and sequential processing being the prototypical procedures.

Influences on the Division of Labor

The variety of ways in which students divided the task put before them by the teacher was not randomly distributed. The two main procedures, sequential and parallel, appeared at specific times of the year. Sequential turn taking was the prevalent procedure in the Fall of the year. This was the time when students were first exposed to working with a microcomputer and teachers used "program control" software. Later in the year, when students had learned more about computer operations and had been exposed to "user control" software, this method of dividing up the task was replaced by parallel forms. A combination of social precedent, the structure of the machine and the design of the software seems to account for this shift in procedures for divding the task.

Social Precedents

Cooperation and turn taking are social values that are usually encouraged in the elementray school classroom. Students have been told on many previous occasions to "take turns" and "to share." Classroom lessons are organized according to turn-taking conventions (Mehan, 1979; McHoul, 1978). Therefore, when students first came to the computer center in the Fall of the year, they may have initially applied their past experience with classroom turn-taking conventions to this new situation. Once they became familiar with machine operations and the difficulties in shifting control of the keyboard after every keystroke, they may have developed new approaches, ones that were appropriate for this new medium.

Machine Design

A microcomputer is designed for one user. It has one keyboard and one monitor. The decision to place two students at a machine designed for one influenced the organization of interaction and academic work. These machine design features contributed to the competition for turns that was so notable between the students in the Fall of the year (see examples #1 and #2 above). Faced with the problem of distributing access, they devised solutions to the dilemma which was imposed by the machine's design. At first, students jockeyed for a position in front of the machine that was more advantageous for entering text. Students rushed to the computer center to gain access to this "keyboard seat." As students gained more experience, they distributed access in more cooperative ways: the duration of turns was longer (the "story" or poem not the key press became the turn-unit) and parallel processing replaced sequential processing.

Software Design

The design features of the software also influenced the interaction that took place between the students. The structure of prompts in fixed choice software (those at the program control end of the continuum in Figure 2) forced the students to consider the possibility of taking turns every time the computer complied with one of their instructions, while the structure of prompts in open ended software (those at the user control end of the continuum in Figure 1) seemed to facilitate parallel actions, those in which one student performed one set of actions while another student performed another set of actions simultaneously.

Summary.

A shift from sequential processing to parallel processing was evident in the three classrooms as the school year progressed. The students' initial use of sequentially organized turn-taking conventions seems to have been influenced by their previous knowledge of classroom activities and the design of the machine. The shift from sequential to parallel processing seems to have been influenced by the design of the the software that the students were assigned to use.

Conclusions

The teachers wanted their students to master the operation of the microcomputer and be able to use the microcomputer for academic tasks e.g., composing poems and editing essays. The teachers started the students' learning process at the computer in a decidely social manner: pairs of students worked together to accomplish assignments. As we stated at the beginning of this chapter, we want to know whether social learning situations are productive. Do pairs of students working together gain benefits that do not accrue to students working alone?

When pairs of students were placed together at the microcomputer, they cooperated in the accomplishment of the task by dividing the labor between them. Sequential processing and parallel processing were the principle ways in which the labor was divided by the students. It was by dividing the labor that students completed the task assigned to them by the teacher. Hence, at the most basic level we can say that the presence of a microcomputer in classrooms for the purposes of instruction is not anti-social; in fact, it has the potential to serve many social functions in the classroom.

Pairs of students placed at a microcomputer for the purpose of writing using software which prompted students to pick from pre-determined choices were found to divide the task sequentially. Some students alternated access to the keyboard every time the machine provided a prompt which resulted in one student responding to a prompt and the other student managing the return key. Other students conducted more operations before turning the keyboard over to the other student. By the third story in a work session in which three to five stories were written, students had settled on the story as the unit in terms of which they would take turns. Once the students settled on the story as the turn-taking unit, one student entered a complete story while the other student provided assistance in the form of comments and suggestions about technical operations of the program and the computer.

Pairs of students placed at a microcomputer for the purposes of writing using software which placed control of the task literally in the hands of the students divided the task in parallel. While one student was engaged in entering text in response to general hints provided by the software, his or her partner was engaged in monitoring computer operations such as the use of the return or control keys and monitoring writing operations such as spelling, grammar, sentence structure and the overall coherence of the composition.

These exchanges point out the possibly productive role of verbal interaction in classroom learning. The students working together talked out loud to each other. These acts of verbalization lead the students to consider alternative formulations of tasks and to restructure tasks in the light of new information.

When the division of labor is examined across the whole school year, a general trend can be detected from sequential processing to parallel processing. The most accelerated point of the transition occurred when the software changed from program controlled to user controlled. For instance, in November, KW replaced "Storyland" (which is a "program controlled" program with "Computer Pals," which is a "mixed Control" program. Concomitant with this shift in software is a shift from sequential to parallel processing. Similar transitions occurred in the other two classrooms as well. Hence, the shift from sequential processing to parallel processing seems to have been influenced by the design of the machine and the design features of the software that the students were assigned to use.

It is interesting to note, furthermore, that students did not revert to sequential processing once they gained experience with parallel processing. KW introduced software during the month of February ("Expository Tool") that starts students at the forced choice end of the software continuum (see

Figure 8 above). Students continued to divide the task in parallel. This suggests that software, while important in determining division of labor patterns, is not the sole determinant. In this case, a new social precedent had been established and was maintained despite software changes.

The relationships between software design and methods of dividing the computer task are shown in Figure 9.

```
Program Controlled              Mixed Control              User Control
    Software                      Software                   Software

<--------------------------------------------------------------------->

Sequential                                                   Parallel
Processing                                                  Processing
```

Figure 9: Software Design and the Division of Labor

CHAPTER 5:

A HOLISTIC APPROACH TO COMPUTER LITERACY

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We wish to thank Liam Bannon for his commentary on this chapter.

"Computer literacy" includes the mastery of machine operations (Bitter, 1982). In many computer literacy courses the mastery of machine operations is taught separately from and prior to computer applications. Students are first taught how to locate machine parts, insert disks, boot programs, manipulate files, operate the keyboard, printer and monitor. Once they have learned machine operations they are introduced to computer programming, usually in BASIC or PASCAL, and then, in advanced courses, to uses such as text editing, spread sheet analysis or data systems management.

The separation of machine operations from computer applications in the acquisition of computer literacy is parallel to the separation of reading readiness from reading in the acquisition of print literacy. Reading readiness is the teaching of the subparts of the reading process, such as sound-letter correspondence, word order and decoding which is taught prior to and independent of engaging in the activity of reading itself.

The separation of machine operations from computer applications is like the separation of reading readiness from reading. Both are atomistic. In both cases, the assembly of the parts of the task (either machine operations or reading readiness) into the whole task comes after students master the components of the subtask.

The teachers in this project adopted a different, more holistic approach to computer literacy. The teaching and learning of machine operations was embedded within academic activities such as reading and writing. Students were not taught machine operations first and computer uses second. Students were taught "keyboarding," disk management, file production, file maintenance and text editing in the context of academic tasks. In any given language arts or mathematics lesson, students were presented with academic tasks to complete. In the process of learning to write essays, generating school newspapers and composing poems, students were also learning the process of using the microcomputer. Correcting the spelling in a student's letter or writing a Haiku poem on the computer required the student to operate the machine as well as read and write.

The teachers' decision to embed the teaching of machine operations within the teaching of machine uses enables us to examine an important question about computers in classrooms:

> Do students develop computer literacy skills when machine operations are taught within the context of academic tasks?

In order to answer this question, we examine students' naturally occurring trouble shooting routines and their performance on a computer literacy test. The trouble shooting routines were the procedures that the students employed in cases of trouble or difficulty when working at the computer. The computer literacy test was a functional, hands on examination of students' computer knowledge administered at the end of the school year.

Students are being asked to learn two things at once when they are learning machine operations embedded in academic tasks. An important issue that arises, then, is whether embedding computer literacy training in an academic curriculum facilitates or interferes with learning. It is possible that the students will learn both about the computer and about academic tasks at the same time and equally well. It is also possible that learning to use a text editor will interfere with the process of learning to write. For example, students' productivity, style and fluency might be suppressed by the difficulty they have in learning text editing commands and manipulating disks.

We were able to examine the holistic approach to computer literacy in two ways: (1) by tracing students day-to-day work at the computer from October to June and (2) by administering a computer literacy test to the students in the project classrooms at the end of the school year. We will examine students trouble shooting at the computer center first, and discuss the results of the computer literacy test second.

Trouble Shooting

In previous chapters, we have identified three phases of the work session at the microcomputer, which we called start up, academic and wrap up.

The students' actions within each of the three phases of the computer work session can be conceptualized as a decision making routine. Students must take a series of actions in order to accomplish the task set before them by the teacher.

<u>The Computer Work Session as a Decision Making Routine</u>

The computer work session starts with the most basic machine manipulations; the students must insure that the power is on and load the correct disks. Once the students are interacting with a program, the decisions become more subtle. The students must select appropriate subroutines (writing, printing, inserting text, deleting text etc). The content of students' work is at the heart of the decision making process. Students choose what text to enter. In the case of program controlled software (explained above), this choice may take the form of selecting among preformed phrases or in the case of user controlled software, this choice involves composing words or phrases. Software and hardware choices appear again after students have finished their work. Naming files accurately, saving text, perhaps printing copies, removing disks, turning off power are included here.

This decision making sequence is depicted in Figure 10:

```
[---[---+---+---+---+---¶---¶---¶---¶---+---+---]---]---]
```

Figure 10: A Computer Work Session Visualized as a Decision Making Routine

key: [or] = a machine manipulation decision
+ = a software manipulation decision
¶ = a content decision

Once students have mastered these steps, the process can become so routine that students' actions do not appear as planned choice or calculations at all. We found it useful nevertheless to characterize the students' interactions with the computer as a decision making routine because doing so facilitated our study of students' learning machine operations embedded in academic uses of the computer.

By focusing on students' actions at each decision making point, the ease and facility of students' progress through the work session could be gauged. Presumably, if students are manipulating disks, selecting programs and engaging the program quickly and effortlessly, then we have a warrant for saying that work session is proceeding smoothly. If, however, students fumble with the power switch, can't load disks, clog the printer with paper and do not work on assigned programs, then we have an indication that the work session is not proceeding smoothly. From this set of assumptions, we make an inference: the more smoothly the students pass over the myriad of decision making points, the better they are performing machine operations.

The warrant for this line of thinking comes from sociological studies of "routine everyday activities" (Garfinkel, 1967) and investigations of what people do when breaks, disruptions or breaches in routine activity occur (Sacks, 1966; Ramos, 1973, 1979; Mehan, 1979: 97-103). Disruptions in routines and the work that people do to re-establish the routine are instructive places to look for an understanding of how people learn to carry out routine work.

When a computer work session is viewed as a decision making routine, there are literally hundreds of decisions to be made. Students traversed the great majority of these decision points with ease. On only a few occasions within a given work session did a student's work routine breaks down. Breakdowns were defined as any disruption in students' work routines. These included:

students paused to consult printed instructions placed around the computer

students selected the help option available within the computer progran

students asked a teacher, observer, aide or other student for help with a problem

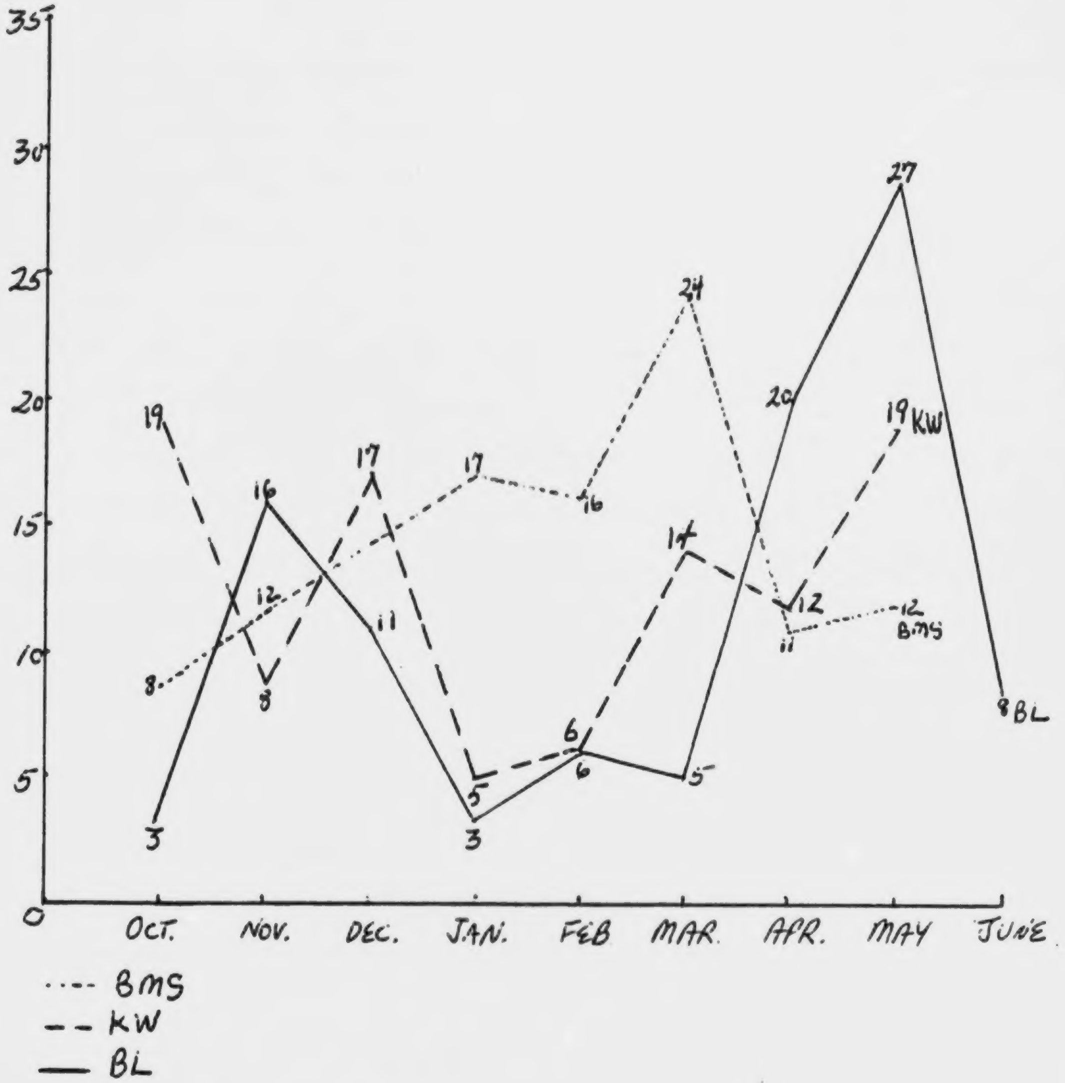
students stopped work to try and solve problems

This way of conceptualizing routine work and disruptions in routines caused coding difficulties which may have influenced our analysis. It is easier to hear students calling for a teacher or peer than it is to see students glance at a wall chart or computer screen. Therefore our conclusions about the relative use of social and print resources must be considered tentative.

Calls for Help and Software Complexity

The problem solving routine at the computer center involves decisions about machine manipulation, software and the content of teachers' assignments. We wanted to know whether students' difficulties were related in any way to the kinds of decisions that they had to make during the course of a computer work session. One could imagine that students would have less trouble with machine operations, software management and content choices as they gained more practice at the computer center. To examine this issue, we calculated the number of calls for help per work session for each month in the three classrooms. The results are displayed in Figure 11:

Figure 11: Percentage of Calls for Help



There is no clear temporal pattern in the three classrooms. While we did not see a linear decline in calls for help during the school year, we did discover a powerful relationship between the type of software assigned and students' calls for help. Differences in the number of calls for help per month was a function of changes from one type of software to another.

All three teachers started the year by introducing their students to "program controlled software." As students mastered the academic tasks inherent in these programs, the teachers introduced software that shifted control to the user. As we explained in Chapter 4, program control and user control software place different cognitive demands on students. When using program controlled software, students insert a disk, select a program from the menu which is presented on the monitor, and form a story or a poem from choices provided on a list. Disk management is limited to a single disk; program management is limited to single letters, the return key and the Control-C function.

Writing with user control software is more complicated. Students must manipulate two disks in order to boot up the programs. While they still choose a program from a menu, they must use more program management keys. In addition to return key and Control-C functions, students must know (I)nsert and (D)rop commands while composing text.

Editing text is even more complicated. Students must master all the disk management operations and program management operations associated with writing, and be able to move the cursor using arrow keys, the Control-I function or jump commands. Disk management is also more complex. Files must be named at the end of a work session and be located on one of a number of disks at the beginning of a new work session.

When the type of software that the students used in a given month is considered, then a pattern of student learning emerges. As Figure 11 shows, students generated 8% of all calls for help in BMS' classroom in October. During this month, they were exposed to Program Control software such as Apple Presents Apple, Science Fiction Story and Master Type. In the following month, they were exposed to The Writer's Assistant, a user control program for composing poems and essays. The percentage of calls for help rose from 8% to 12%. The students continued to use this software for the next two months. There was a slight increase in the number of calls for help during this period, 17% of all calls for help occurred in January, while 16% occurred in February. In March, BMS increased the complexity of the students' tasks at the computer. They participated in Computer Chronicles Editorial Boards and became responsible for editing students' newspaper stories. There was an accompanying increase in students' calls for help during this period; 24% of all calls for help occurred then. Students continued to write and edit for the remainder of the year, and we see a decline in students' difficulties during the final months of the school year. Only 11% of all calls for help occurred in April and 12% occurred in May.

A similar pattern existed in KW's classroom. She introduced her students to Storyland and Apple Presents Apple in October; the students registered the most calls for help during this month. In November, the task shifted to editing previously written text; we found a decline in calls for help from 19% to 8%. In December, another new task was introduced. Students were called upon to write on their own; the calls for help increased from 8% to 17%. The assigned task between January and April was similar to that assigned in December, and we found a decline in calls for help. The students averaged 9% calls for help during these months. During May, KW changed the task from writing to editing on the computer; we found the same increase in calls for help in this classroom as we found under similar circumstances in BMS' classroom. Twelve percent of the calls for help occurred in April (when students were writing at the computer) while 19% of calls for help occurred in May (when the students were editing at the computer).

The age of the students in BL's classroom had an influence on the relationship between students' mastery and software complexity. Her students had more trouble mastering the program control software than did the older students in BMS' and KW's classroom; 27% of calls for help occurred in November and December. BL continued the use of this software into the Winter months, and gradually moved the students down the continuum of control by using software like the Horus stories and Storyland. We found a sharp decline in calls for help during these months; 3% of calls for help occurred in January, 6% in February and 5% in March. In May, BL introduced the students to composing stories at the computer. This shift from program control to user control software was accompanied by a sharp increase in the students' calls for help; 27% of all calls occurred in May.

In general, students experienced initial difficulty with computer operations and program manipulations, and then gained control of them. The shift to a more complex task was accompanied by an increase in students' difficulties as indexed by student calls for help. As students worked with the more demanding programs, they mastered more complex routines.

The Transformation of Problems

The relationship between students' mastery of computer operations and the complexity of software is even more pronounced when the type of errors that students made through the school year is considered. Students did not ask people to help them with the same kinds of problems throughout the year. They called for help with more sophisticated and subtle aspects of computer and software operations as the year went on. Recall the conception of the work session as a decision making routine depicted in Figure 10 above. In these terms, students at first ran into trouble with the first and last steps in the computer using process, then had trouble managing the software, and finally had trouble with decisions about the content of their entries.

Program Control Software and Computer Operation Difficulties. When students were first exposed to the computer in the Fall of the year, they ran into trouble with initial steps in the computer using process. They did not know how to turn the power on; they inserted the disk in the disk drive upside down. They expressed concern at the "blinking red light" on the disk drive; since it was red, they thought there might be danger. The blinking cursor also led some of the students to express dismay. They often had trouble going through the sequence of steps involved in booting a program. Once they booted a program, they had trouble locating a program on the disk.

Saving and printing text at the end of a work session also caused students considerable difficulty in the beginning of the year. They often tried to save a file with the wrong disk in the drive. They didn't know whether they should print a file or not.

Initial Use of User Control Software and Software Manipulation Difficulties. The introduction of new and complex software into the students' learning environment introduced new and more complex problems for the students to solve. These new problems did not seem to be added on to previously existing problems, however. Instead, what had previously been considered to be a problem was mastered and became routinized. Old problems were replaced by new ones.

When students graduated from program control software to the initial stages of user control software the source of their problems shifted as well. By November in KW's classroom, December in BMS's classroom and January in BL's classroom, students had the steps in the Start Up and Wrap Up phases of the computer work session under control. There were fewer calls to adults to help with disk insertion, on and off switches and disk selection. Students had less difficulty getting the machine ready for work. Now calls for help focused on the use of software, not on the use of the machine.

Once they booted a program, students constantly forgot to press the keys that shifted the program into different modes (e. g., the I key for inserting text, or forgot to press the return key after text had been entered). Another recurrent type of problem that plagued students when they first encountered user control software was accidently pressing incorrect keys and not knowing how to recover from the situation. The Control-C key (which signals the completion of a computer operation) was often pressed instead of keys that enable text to be inserted (i. e., Control-I). Or students attempted to enter text without setting the computer to the insert mode. When students began pressing keys to enter text, the computer, not set to accept instructions, often threw the students into strange places, including program language.

When students finished working on a text file, they were instructed to name the file according to certain procedures so they could find their work at a later date. Naming and locating texts that had been named previously caused students difficulty at this stage in the development of their computer mastery. Likewise, they confused the disks that controlled programs with disks that stored students' files. These problems, which are concerned with more technical aspects of machine operations, accounted for the bulk of the calls for help from students to adults when students first encountered user control software.

User Control Software and Difficulties with Editing Commands

Concommitant with the shift to composing texts and editing them at the computer (tasks at the "user control" end of the software continuum), we found a shift in the situations that caused students trouble, which in turn led them to call for help. For example, the students had problems throughout the year with the editing commands of the word processing system. However, the nature of the problem shifted from those associated with initial processes (e. g., beginning to type without first pressing the appropriate command key--Control I for (I)nsert, or forgetting to press Control-C when ending an (I)nsert, to problems of a more conceptual nature. Evident when students began writing and editing were problems such as:

> Adding new text at the end of a line when the cursor won't move past the end of the text;
>
> Moving sentences or larger units of text;
>
> Adding space between blended words or sentences (e. g., between the two e's in Theend);
>
> Exchanging text within a sentence (e. g., text for test);
>
> Aligning the title of stories or poems in the center of the page.

While students spent time wrestling with these problems, their previous difficulties with program booting and final machine operations did not continue to plague them. These problems had been solved, and were now incorporated into the routine of the work session.

The Use of Social Resources in Trouble Shooting

Another way to look at students' mastery of machine operations and uses is to consider the sources that students consult when they need help. In order to obtain this information, we computed the number of times that students stopped the routine of the work session, and "called for help" with their work. We then determined where students turned for help when these disruptions in their routines occurred. This information is presented in Table 2.

Source of Help

	Adults			Students		Written		T/E	
Classroom	Tchr/Aide	Obs	Tutor	Partner	Peers	Instr	Screen		T
KW (N=315)	23%	30%	05%	07%	07%	18%	04%	06%	100
BMS(N=450)	11%	58%	--	09%	05%	11%	04%	03%	100
BL (N=258)	12%	55%	01%	06%	01%	11%	04%	05%	100

Table 2: The Sources of Students' Calls for Help in Computer Work Sessions

[key: Tchr/Aide--Teacher or Aide
Obs--Observer from Research Team
T/E--trial and error; an individual search]

The students in all three classrooms called upon the observer most frequently, and the teacher second most frequently, when they needed help. Students turned to the written instructions about computer use posted around the work station third most frequently. The student's partner was the next most frequent source of help when difficulties arose in KW's and BMS's classroom, while instructions available on the computer screen were the next most frequently called upon by BL's students. In short, social resources were the most predominant source of help when students ran into trouble at the computer.

The predominance of social resources becomes even more apparent when the categories in Table 2 are collapsed as in Table 3 below:

	Sources of Help			
	Adults	Students	Printed Instructions	Trial and Error
Classroom				
KW	53%	19%	22%	6%
BMS	69%	14%	15%	3%
BL	67%	08%	20%	5%

Table 3: Major Categories of Calls for Help

Here we see more starkly that adults were called upon for help most often. Printed instructions were consulted more often than peers were called upon, but the calls for help to adult and student sources combined far outweighed consultations of instructions posted at the computer and available on the computer screen.

The relatively infrequent use of information sources in these classrooms is linked to the problem solving theme discussed in the cognitive sciences literature. One need look no further than Simon's (1949) Administrative Behavior for a discussion of the use of convenient strategies in problem solving. He describes "satisficing" as the way that people solve problems which involves the selection of the first available option or solution that gets a job done. Satisficing is often contrasted to "optimizing" or other formal operational procedures in which the problem solver is expected to run through the full range of all problem solving routines, selecting the best one, not just any one that will do. With his emphasis on satisficing, Simon is pointing to the practical element in problem solving; people do not necessarily employ the optimal problem strategy if a suitable and convenient one will do.

The students at the computer had a range of options available to them in time of trouble (teachers, observers, aides, other students, instructions on the screen, instructions posted around the computer and each other). From the standpoint of the teachers' long term goals for students' learning, the selection of written instructions or individual problem solving (what we have been calling "trial and error" here) would be seen as optimal. Yet the students overwhelmingly called upon the observer and the teacher which were much more convenient and immediate ways to solve problems.

Social Resources and the Local Expert

Our finding that students turn to social resources rather than printed materials or on-screen instructions when they have trouble working at the computer is consistent with recent work in the field of human-machine interaction (Bannon, personal communication, 1985; Norman and Draper, 1975). Scharer (1983) reports that only 10-15% of several dozen data processing trainees who were taught using long and thorough user guides consulted them during initial training and in work sessions observed 6 months after the completion of training. Instead of consulting manuals, the trainees listened carefully during demonstrations and took notes. Notes were referenced continually, but the manual was not. Within each group of trainees, one or two quickly understood the material and became local heroes by helping others. Most of this teaching was "show and tell" not "write and read."

This pattern of relying on "local experts" accompanied the trainees when they finished training and went to work. New users were trained by more experienced users, again by show-and-tell rather than through manuals. People who had learned the system were consulted for answers to pressing problems. These local experts were not necessarily in positions of institutional authority; they had developed local and relevent knowledge and were called upon when needed.

In Scharer's terms, the students in our project's classrooms were treating the observers, teachers and some times each other as local experts. The observer was known to the students, afterall, to be a knowledgeable computer person and was sitting within 5 feet of the students at the computer center. And teachers are the conventional source of knowledge in students' eyes. When students were called on, those who had just completed a work session at the computer center were most often treated as local experts. Students who were having trouble sought out students who had recently left the computer center for advice, perhaps using the logic that they may have encountered and even solved similar problems.

When local experts responded to students' calls for help, they, like the adults in Scharer's study, adopted a "show and tell" and not a "write and read" mode of instruction. They sometimes took over the keyboard from the students who were in jeopardy and performed the operation that was causing difficulty. They also demonstrated the relevent operations so that the jeopardized students.

The mode of instruction that developed between local experts and students has more in common with informal education (Greenfield and Lave, 1983; Scribner and Cole, 1973) than it does with the formal mode of instruction usually associated with one classroom. Students learning from each other and other local experts employed the show and tell, observe and demonstrate techniques that are associated with expert weavers and tailors teaching their apprentices. They did not employ the verbal mode of instruction they so often encounter with their regular classroom teachers.

Summary

Pairs of students at the computer worked together on language arts tasks. The students made a series of decisions in the Start Up, Academic and Wrap Up phases of the computer session in order to complete the assigned task. For the most part, students were very efficient in carrying out this decision making routine. Students checked the power source, loaded the correct disks, selected the appropriate program, chose the appropriate subroutine within the program. When finished entering text, students made files, printed copies, removed disks and turned the power off.

On some occasions, the smooth and fluid flow of the work routine was disrupted. Students had difficulty operating the machine, handling the software or deciding what to write and how to manipulate software commands in order to write. We found that these disruptions, or breaches in routines, were productive places to look for information about the organization of routine interaction.

When students had difficulty with machine operations, program manipulation or text editing commands, they called for help. The adults in the classrooms--teachers, observers and aides--were called upon most frequently by students when they ran into trouble. The instructions about computer use posted around the computer center were the next most frequently consulted resource when students called for help.

Measured in terms of sources consulted in time of trouble, at least, the students in these classrooms can be characterized as choosing the most immediate and available solutions when problems in the decision making routine at the computer arise. The use of this "satisficing" strategy resulted in the exploitation of social resources in the form of local experts.

In order to determine whether students' difficulties were related to the kinds of decisions that students had to make, we considered whether students had fewer difficulties as the year went on, that is, as they gained more experience at the computer. While we did not see a linear decline in calls for help over the course of the school year, we did discover that the complexity of software had a strong influence on the frequency of students' difficulties. Students experienced more difficulty and called for help more often when they were introduced to software that placed greater cognitive responsibility on them. Students' difficulties (as indexed by their calls for help) increased in the months in which the teachers shifted from program control software, i. e., in which the students had to manage only one disk and formed stories and poems by selecting options from pre-determined lists, to user control software i. e., in which students had to manipulate more than one disk, name files and enter text free style. The initial difficulty that students experienced when introduced to more complex software diminished. As students worked together with the more demanding software, they mastered the new and more complex routines. Their calls for outside help declined. Thus, instead of a straight line decline in students' reliance on outside help, we found a more jagged learning curve. When confronted with more complex software, students' difficulties increased initially, but declined as they entered new skills into their work routine.

The students' mastery of more complex computer routines was made more visible when the types of errors that the students made throughout the school year was considered. Students did not call for help for the same kinds of problems in the Spring as they did in the Fall. They called for help with more sophisticated problems as the year went on. In the Fall of the year, when user control software was used, the students had difficulty with the first and last steps in the computer using process, i. e., machine operations. In the middle of the school year, students had trouble with the stages of the decision making routine associated with software manipulation, i.e., naming and retreiving files. At the end of the school year, the students had most of their difficulties with subtle editing routines, such as adding new text, exchanging new text for old, and moving text from one part of an essay to another.

Thus, while students continued to rely on social resources throughout the school year (i. e., during the shift from program control to user control software), they did not call upon help for the same problems. The calls for help were about more technical problems later in the year than earlier in the year. This pattern of trouble shooting is an indication that the students obtained a deeper level of understanding about the software and the computer through their experience with a holistic approach to computer literacy.

Testing Computer Literacy

This examination of students' trouble shooting routines in naturally occurring work sessions at the microcomputer gives us considerable insight into the utility of teaching computer operations within the context of computer uses. These results are reinforced by our examiniation of individual students' performance on a computer literacy test.

Members of the project designed a functional computer literacy test which was designed to measure students' knowledge of computer functions and ability to use the computer. It was a "hands on" test. Students performed actions at the computer in response to questions asked by a member of the project staff.

Part I consisted of eight questions about the parts of the computer system. Students were asked to label computer components and explain their function. Questions were included about computer parts that had never been mentioned in the classroom like the Central Processing Unit. Complete or perfect answers were awarded 2 points, incomplete or partial responses were given 1 point. No responses or incorrect responses received 0 points.

Part II required the student to use the software to enter text, save the text on disk and print a copy of the text. This involved a sequence of about 10 steps. A perfect score of 20 was given to a student who was able to complete the sequence with no help or prompting from the tester. One point was subtracted if prompting was required for any step. Two points were subtracted for any step that the tester had to do for the student or direct the student to do.

The last section of the test consisted of questions and student demonstrations. The students were asked to edit the work of another person. The textfile stored on a disk used a coding system that was different but similar to one that they had used in their classroom. Once they had located the file, the students were asked to make certain changes. Students' answers or actions were scored as either correct and/or efficient (2 points) or incomplete and/or inefficient (1 point).

The computer literacy test was given to six students in KW's and RR's classrooms, 4 in BMS's classroom and 5 monolingual and 6 limited English proficiency (LEP) students in BL's classroom. The students were selected in the following manner. The class list for each of the classrooms was reviewed and any student for whom we did not have a complete set of pretests was excluded. Teachers were then asked to group the students into three categories, students who seemed to be doing well on the computer, students who were average, and students who seemed to have more difficulties. Two students were selected from each of the groups based on coordination of the student's free time, the tester's schedule, and the availability of the computer.

The test was administered individually. Students were told they would be asked about things they had not learned. Students took from 30-40 minutes to complete the test. The test consisted of three parts: (1) knowledge of computer vocabulary and computer functions, (2) demonstration of ability to enter, store and print text, (3) demonstration of ability to edit text. (See appendix for a copy of the test).

While many of the students achieved perfect scores on Part II, there were no perfect scores on Part I or III. This was because the students were asked to give information or demonstrate procedures that they had never before encountered in classroom instruction. In fact, the teachers questioned the inclusion of items that they were sure their students would not know. They were included to give students a chance to demonstrate their ability to make inferences from what they did know, and to utilize information that is available from the software.

Table 4 shows the average number of points scored by the students in each of the classrooms.

Table 4:
Students Average % of Correct Responses on the Computer Literacy Test

	Part I: 32 points	Part II: 20 points	Part III: 39 points	Total 91 points
3rd-4th (BL)				
Bi-lingual n=6	41	43	22	33
English n=6	59	51	33	46
Total	49	47	27	39
4th (BMS) n=4	69	90	54	67
5th-6th (KW) n=6	78	95	56	73
5th-6th (RR) n=6	74	99	80	82

With the exception of the youngest bilingual students, almost all of the students were able to demonstrate how to write, store and print text with little or no prompting. In addition, most of the students had learned the terms and functions of most of the computer parts, peripherals and software, even though they had received no direct computer literacy training. They were all familiar with the basic editing commands, and many of the students were able to demonstrate one or more advanced editing commands that had not been taught by the teacher.

The test results of the students are congruent with their observed performance on computers in the classrooms as well as the teachers evaluation. The younger students (BL's students) had the most difficulty mastering the software over the course of the year. They scored the lowest on the test. (Some of the reasons for this have been dealt with in more detail in Chapter 3.) These students scored highest in Part I, which dealt with knowledge of the computer's parts and functions. It appears that they were able to learn almost as much about the system as the older students even though they experienced more difficulties in using it.

The highest scores for the more proficient students are in Part II of the test. The discussion on trouble shooting earlier in this chapter indicated that the calls for help at the beginning and middle of the year were concerned with issue of writing, storing and printing textfiles. These tasks remained difficult for the 3rd-4th graders in BL's classroom even at the end of the year. In the upper grades, the students learned how to do these tasks so well that there were many perfect scores in this part of the test. This performance as well as the decrease in calls for help concerning these procedures indicate that these students, with a wide range of classroom skills, had all mastered the mechanics for writing with the computer.

The performance on Part III indicates the students' control of the computer for editing and revising texts. Editing and revising were introduced midyear; they are skills that students slowly acquired over the last months of the school year. Many of the calls for help during the later part of the year dealt with problems that the students had with the more difficult tasks of editing. The students were scored not only for accomplishing tasks on this part of the test, but also for doing them in the most efficient way. For example, using the space bar to move to a location several lines away was not scored as high as using the RETURN or down arrow keys. Similarly, using one command to make a change was scored higher than accomplishing the task with two or three commands.

Another indication of the students' mastery of the technology is the ease with which they were able to handle changes in the system. Students in BL's and RR's classroom were tested with computer systems that were slightly different than those that they had used in their classrooms. In BL's classroom, the students were tested on an Apple II+ computer instead of the Apple IIe they had used all year. This switch in hardware presented students with new experiences. For example, when the students could not find the up/down arrows they were told to use the o and l keys. They were able to make such adjustments with no difficulty. In RR's classroom, students who had worked with a two drive computer system were tested on a one drive system. They were able to follow the directions in the software for removing and replacing disks even though they had never followed the sequence in the classroom.

The students' overall performance on this test indicates that students learned the vocabulary and functions of the computer components and how to use a word processing system for entering and editing text.

Conclusions

School districts are developing entirely new curricula for teaching students about the operation of the computer. Many of the courses in computer literacy curricula teach machine operations separately and distinctly from the uses that the computer can have for academic and occupational purposes.

Four teachers taught their elementary school students about computer operations within the context of teaching them about computer uses, including writing and editing. Students spent on the average of 25 minutes a week in language arts and 25 minutes a week in mathematics at the computer. This means that they had 15 hours at the computer by the end of the school year. The students in these classrooms learned to write and edit using a microcomputer, and, they learned to operate the machine without a specific and special course designed to teach them about the machine.

If our modest results can be replicated, they have broad implications for teaching computer literacy. This study suggests that it is not necessary to develop a special, separate and independent curriculum called computer literacy. Instead, the teaching of machine operations can be embedded in the teaching of academic tasks. We have had some success placing computer operations within a language arts curriculum. The same principle should also apply to math, science and social studies.

In addition to being cost effective, the holistic approach to computer literacy takes advantage of the highly motivating characteristics of microcomputers (Malone, 1981). Students are exposed to information about computers while using them to learn important educational material. If computer literacy is decontextualized by having students learn about the computer without leaning what it can do, then the motivating elements can be lost. In so doing, we fear that computer literacy requirements can become yet another academic hurdle for students to jump over rather than being a meaningful educational experience in which usable skills are taught in understandable ways.

Computer programming plays a different role in this holistic approach to computer literacy than it does in many computer literacy curricula. Instead of making computer programming the single entry point and pinnacle of computer literacy, we are suggesting that it is important to provide students with "multiple entry points to expertise" (Levin and Souviney, 1983). Multiple entry points enable students to use computers as powerful tools for a wide range of applications. For some students, that power will come through the ability to program the computer. But, for others, that power could and should come, we feel, from knowing how to use the computer, to write and edit text, to create music, graphics and animation, to organize information and to communicate it to others. Furthermore, one avenue of access does not preclude another. Just as the student who begins learning about computers by programming them is not precluded from assembling spread sheets later on, so, too, the student who learns text editing first is not precluded from learning to program later.

Like other investigators of human-machine interaction, we found that computer users consulted social resources more often than printed materials and manuals. There are lessons to be learned from these observations about the nature of instructions given to students who are learning to work at computers and the design of user guides.

While thorough users' guides and brief instructions must continue to be available to people learning to operate the computer, it does not seem to us that manuals should be the primary resource in teaching. Instead, teachers can capitalize on the seemingly ubiquitous presence of local experts. In each of the classrooms there were students who were highly motivated and knowledgeable about computers; we are recommending that teachers systematically exploit this expertise by encouraging students who are learning about computer operations to seek out these "computer tutors" (as KW called her local experts).

It is also possible to empower students with knowledge about the computer. Diaz (1984) has been exploring this idea in an after school program in South East San Diego. He selects students who have been having academic difficulty or have not routinely enjoyed high prestige in the eyes of peers and gives them special knowledge about computer operations. Other students soon learn that they can obtain special help from these experts. The resulting transactions seem to be mutually beneficial; the students in need of help gain it, and the previously unsuccessful student gains experience with success.

While calling for the systematic use of expert students in the computer center, we are not recommending the elimination of written instructions or manuals entirely. Particularly helpful are brief instructions which can be arranged around the keyboard and monitor. The project teachers started the year with general instructions about machine care and basic text editing commands. When they started a new activity, they posted specific instructions that were relevant to the new task on or near the computer. By the end of the school year, the computer was quite literally papered over with notes, reminders and penciled in notations. To a visitor or first time user, the computer and its paper cloak seemed imposing if not impossible to fathom. But students, socialized into each new layer of activity with its accompanying instructions, seldom had difficulty in consulting the appropriate special note, even though it may have been buried beneath weeks of similar kinds of notes.

In addition to a brief list of generic commands and specific lists of instructions, our experience tells us that a different kind of instruction also needs to be posted at the computer center. Diagnostic instructions need to be available to students. These diagnostic instructions take the discourse form of "if you have a problem, then do x." Two such diagnostic instructions used by KW with her 5th and 6th graders are duplicated below.

GET ME OUT OF HERE

If you need to "get out" of a program or back to the beginning, try these in order.

- Push ESC
- Push Q
- Push CONTROL & RESET
- Push PR#6

NO LUCK?

CALL

COMPUTER TUTOR

Warning! **DO NOT** turn the computer off

WHEN IN DOUBT

(Help Me! Help Me!)

If the computer is not doing as you think it should, try one of these before you call a computer or a teacher

- Is it plugged in?
- Is it turned on?
- Is the monitor on?
- Did you push RETURN?
- Did you push CONTROL-C?
- Did you read the screen for further directions?

If you can answer, "yes," to all of these questions and you still can't get results...

CALL
COMPUTER
TUTOR

The intent of diagnostic instructions is to encourage students to first, initiate locally organized trouble shooting routines on frequently occurring problems, and second, initiate calls for social help in a prescribed sequence. Peers and computer tutors are to be consulted before teachers. Specifying the order of calls for social help is intended to lessen students' dependence on the teacher and foster student initiated actions.

CHAPTER 6:

FUNCTIONAL LEARNING ENVIRONMENTS FOR WRITING

Margaret M. Riel

When considering the educational applications of microcomputers in classrooms, the issue is how they can be used to achieve important educational goals, ones that could not be achieved as readily without them. Dewey (1916:118-129) claims that educational activities are appropriate when they begin with the experience of students and, through a planned sequence of steps, move in the direction of what experts know and do. Educational goals are flexible guides to activity for Dewey, easily modified by learners and teachers alike.

We began by exploring the educational goals of the teachers in language arts and tried to find ways to use the computer as a tool to accomplish them. One goal of language arts instruction formulated by the teachers was the integration of reading and writing activities throughout the curriculum, the view that reading and writing are coordinated. From this point of view, reading is not confined to reading circles. It is carried out and encouraged throughout the school day, during "reading time" as well as in content areas such as social studies and science. Writing plays a major role in such a language arts curriculum. Students are given time to write in personal journals, compose essays on topics generated by the teacher and write about what they learn in science and social studies.

Another goal stated by the teachers was to help their students to understand writing as a process from initial organization of thoughts to a final copy produced for a particular audience. Realizing that adult writers do not produce finished drafts in one sitting, they wanted their students to be able to organize and collect ideas for writing, create a draft, receive feedback from others, and work it through final editing and revision—a process that unfolds across several working sessions (Miller-Souviney, 1985).

In close collaboration teachers and researchers sought to create activities which extended the interests and experiences of students in ways that accomplished the educational goals of their teachers. This coupling of student interests with educational goals become the basis for creating what we have come to call "functional learning environments."

A Functional Learning Environment: The Computer Chronicles

Functional learning environments in language arts are those in which reading and writing are organized for communicative purposes, rather than just as an exercise for a teacher to evaluate (cf. LCHC, 1982; Newman, 1984). We used a computer network, the "Computer Chronicles Newswire" (Levin, Riel, Boruta, & Rowe, 1984; Riel 1985) to explore the use of the microcomputer to support reading and writing for communicative purposes. Via the Computer Chronicles Newswire, students were connected to a distant, inaccessible audience with which they wanted to share ideas. This writing for communicative purposes and not just writing on a microcomputer had positive effects on the writing process.

The Computer Chronicles Newswire is a writing network that links together schools in different locations, including Alaska, Hawaii and California. Students from classrooms in each of these locations wrote and edited stories about local events which were stored on floppy disks. The disks were sent to all sites participating in the network. Students at each site used articles written by themselves as well as by other students in the network to publish their own local version of the Computer Chronicles Newspaper. Each of the classrooms in our project was connected with each other and other schools in this news network. All the students were involved in writing newspaper articles which they hoped would be published in their newspaper, as well as in other school papers. This activity facilitated the teaching of writing as a process (Cooper and Odell, 1978; Graves 1978) including pre-writing, planning and organizing, writing, response, revision and evaluation and post-writing phases.

The students in the project classrooms were involved in a writing environment that was similar to that of professional writers. The Computer Chronicles News Network was explicitly modelled on existing news wire services. Whenever possible, students' attention was called to the parallels between their work and the work of newspaper reporters and editors. Like adults, their writing was constrained both by the audience for which they wrote, and format requirements of newspaper stories. The quality of the student work was judged by peers and the need for revision was made a natural part of the cycle.

Interactive software which provided the student with suggestions and writing guidelines was used to provide them with "dynamic support" in the pre-writing and composing phases. It helps narrow down the subject of their articles by making choices. Once the students were ready to write a particular type of story, they were given appropriate guidelines or suggestions. The software helps extend the "pre-writing" phase into the writing of the first draft.

While the computer and printer were important tools in the creation of their newspaper, these tools were used as one part of a larger activity. Many of the learning experiences involved in creating a newspaper took place away from the computer. Students met in small groups to edit each others work and to read, evaluate, and select articles for their newspaper. This project provided a way to integrate computer use with a range of language arts and social studies activities.

The Effectiveness of Computer Supported Writing Environments

In the following sections, we will examine student performance to see whether the creation of a functional learning environment had an effect on students' reading and writing skills. Data collected from four classrooms (described below) will be used to address the following questions:

What effect do functional writing environments have on the writing fluency of the students?

What effect do functional writing environments have on the quality of students' writing.

What effect does collaborative writing and peer review have on the students' writing abilities?

Each of these questions will be addressed separately, employing four different forms of data, (1) standardized testing administered by the school districts, (2) Pre- and Posttest measures collected as part of the project assessment of students' skills, (3) samples of the students' classroom work written on paper and on the computer and (4) audiotapes of editorial board discussions.

Standardized Testing: California Test of Basic Skills

The California Test of Basic Skills (CTBS) is a standardized test that is given by school districts to all elementary school children at least once a year in September or May. CTBS gives students' grade level equivalents in the areas of math, reading, language arts, science and social studies, as well as an overall score. Some of the schools tested only a portion of the students or used only some of the subtests. Two of the project classrooms, BMS's fourth grade and KO's fifth-sixth grade, had test results in all areas for most of their class.

Writing Pre- and Posttests Essays

We were particularly interested in descriptive writing because of its importance in writing newspaper articles, an activity present in all classrooms. We selected two descriptive writing tasks, one asked students to describe a pet and the other asked them to write a news report about a school event. Since the description of an event at school was more closely related to students' newspaper writing, we expected to see the most change in this pair of essays. These are the two writing prompts used:

> Description of a school event Imagine you are a reporter for a national newspaper. You have been asked to write a story about something that has happened in your classroom or at your school. It could be something that happened in your reading group, during math time or on the playground. It could be about a special visitor that came to your class or school, a class activity or a school assembly. Think about what happened, who was involved, when it took place and why it happened. Write a story that tells other students about this event.
>
> Description of an animal Imagine you have been given a new pet. Perhaps you have been given a cat, dog, rabbit or a fish. Think about how big the pet would be and what color it would be. Think about how all the parts of the pet would look. Also think about what noises the pet would make and about how the pet would feel when you touched it. Describe the pet you have been given. Tell how that pet would look, sound, and feel.

All students were given the assignments by their classroom teachers at the beginning and end of the year. The students worked individually and the essays were written on paper. They were not timed; the students were given as long as they needed to write the essays.

The length of an essay was determined by counting the number of words in the body of the essay. The title and any byline information were not included in the word count. Numbers were counted as words. The quality of the essays was determined by a method of "holistic" scoring described in Grubb (1981). The tests were scored by three persons who did not know the students. The writing samples were given a score from 0-4 using a four point evaluation rubric for descriptive writing (Grubb 1981:29-33):

> 0 was given to a composition that did not address the prompt
> 1 for an inadequate composition
> 2 for an adequate composition
> 3 for a good composition
> 4 for an excellent composition.

The evaluation rubric is in the Appendix.

The scores given by each of the three readers were averaged. These scores form an ordinal scale which are very similar to the numerical values given to grades. We will report "grade point averages," acknowledging that the scoring is ordinal in nature in that the difference between the values may not reflect the same degree of improvement.

Classroom Writing Assignments

The students' writing samples over the school year provide further evidence about the influence of functional activities on the length and quality of students' essays. Teachers were asked to provide a sample of students' work about once a month. When possible, the assignment was collected on the days that videotaping was done in the classroom. All the writing samples discussed in this section were written by individual students on paper.

The length of the essays were determined by counting the number of words in the essay (excluding titles and bylines). Papers for which a word count was not appropriate, such as poems and responses to a series of questions, were not included in the sample. The papers were grouped into three periods, Sep-Dec, Jan-Mar and Apr-Jun, and the average length of papers written in each period was computed.

The essays scored for length were then scored for quality by using the following modified holistic scoring technique. The teacher's reported goals for the assignment, as well as the directions presented to the students, were used to determine the writing prompt. A four point "evaluation rubric" was selected from Grubb's (1981) that was most appropriate for the form of writing (descriptive, narrative, expository or persuasive). One scorer assigned 0-4 points to each essays based on the evaluation rubric. The average score of the papers written during each of the three periods, Sep-Dec, Jan-Mar and Apr-Jun, is presented in the discussions of quality of writing in each of the classrooms.

Writing in the classroom on the Computer

It was more difficult to determine the set of essays written with the computer because the students almost always worked in pairs on the computer and partners were changed. Rotating partners gave students opportunity to work with a range of other students, but made it difficult to assess individual improvement. Assignments took longer to complete because of limited access to the computer. Some of the writing activities involved interacting with partial texts provided by the computer program. Papers written earlier were revised during a later period.

At the same time students completed a number of different writing activities on the computer over the year, all classrooms participated in some form of newspaper writing. To avoid some of the confusion of dealing with different revisions of an article, we used only the final copy of articles selected by the students for publication in their classroom newspapers. This enabled us to compare the length of computer generated newspaper stories with those written on paper by the students in KO's classroom which did not have a computer.

The different editions of the newspapers from each of the classrooms were used to assess changes in length. Only stories in paragraph format were used for word counts, a choice which excluded all jokes, recipes, poems, puzzles, survey reports in table form and interview transcripts. With the exception of the newspaper from BL's class, all newspapers included stories written by students from other classrooms.

The modified holistic scoring procedures describe in the previous section were used to rate the newspaper stories on a 0-4 point scales. All articles that were scored for length were also scored for quality.

Four classrooms participated in this study. In three classrooms, the teachers used computer writing tools to teach language arts. In one classroom, the teacher taught reading and writing in a way which was similar to the other teachers, but without the aid of the computer. Differences in the age and ability levels of the students and differences in teacher knowledge and experience make it necessary to report on each of the classrooms separately.

Description of Writing in BMS Fourth Grade

BMS began the year with many resources for integrating the computer into the writing curriculum. She had been trained to teach writing as a process through the San Diego Area Writing Project's Summer Institute Program and had experience implementing this approach with students at different grade levels. She also had prior computer experience and had used and created Interactive Tool software.

The majority of students in her class were of average achievement in language arts and reading as measured by the California Test of Basic Skills. She also had a number of limited English proficiency students.

As described in Chapter Two, BMS taught writing in a series of steps. She began by introducing the assignment and then helping students either together or in small groups to collect their ideas and plan their writing. In this prewriting phase, the students often made lists of words or phrases to use as a reference when writing the first draft. When first drafts were written on paper, students usually worked individually; when they were composed at the computer, the students worked in pairs.

Most writing assignments on paper were assigned to improve writing fluency. For example, students were asked to write about personal experiences, to express feelings or wishes, to discuss topics like friendship, to describe objects, to share information and to give directions. Students spent some time each week in this type of writing. The papers were read by peers and then by the teacher. Some papers were collected and returned to the students with brief comments.

Some of the writing done on paper and most of the work composed on the computer was intended for audiences beyond the teacher. The "first drafts" of these papers went through several more steps of the writing process. They were often circulated to other students in small "response groups." Students read each other's writing and offered suggestions for improving the writing. Their suggestions focused on both the content and form of the papers. After the writers received the feedback from their peers, they were then given the time to revise their drafts. This response and editing of papers replaced the more conventional "language" or grammar exercises traditionally used to teach writing mechanics. The final copies from this process were then displayed, published or sent to students in other classrooms. This final step, referred to as post writing, was as the teacher later wrote "the engine that drives the writing process" (Miller-Souviney & Souviney, 1985).

Writing assignments on the computer took more time to complete because all the students were required to cycle through the computer center twice, once for the first draft and a second time for the revision. Computer writing assignments took place in two week cycles; they included newspaper articles, computer-pal letter writing, poetry and narrative essays.

Newspaper writing was a central focus of the writing curriculum in this classroom and most of the students participated in the project regularly. All but 5 students wrote at least one article in one of the three newspapers they published. Each newspaper carried stories from about half the class. The stories for each edition of the newspaper were selected by students serving on editorial boards. The role of the editorial board was to read and evaluate all articles written for the current issue of the classroom newspaper. They were also responsible for final editing layout of the newspaper.

To serve on an editorial board students had to volunteer to give up some of their free time to accomplish the work. About 2/3 of the class was interested in assuming this role; 4 to 5 students were randomly selected from volunteers to edit each edition of the newspaper. About half the students served on one of the three editorial boards.

Length of Essays in BMS's Classroom

The length of the students writing on paper and on the computer increased gradually and steadily over the course of the year. Table 5 shows the length of the different writing assignments at selected time points across the school year.

Pet Desc.	Sep (pretest)			Jun (posttest)
Mean:	X=48 (n=25)			X=106 (n=25)
SD:	(35)			(64)
Event Desc.	Sep (pretest)			Jun (posttest)
Mean:	X=65 (n=22)			X=84 (n=22)
SD	(33)			(61)
Classroom essays	Sep-Dec	Jan-Mar		Apr-Jun
Mean:	X=42 n=65	X=60 n=66		X=78 n=59
SD	(23)	(30)		(58)
Newspaper articles		Feb	Mar	June
Mean:		X=53	X=66	X=80
SD		(18)	(49)	(52)
		n=14	n=14	n=10

Table 5: The mean length of three types of writing assignments from September to June in BMS's Classroom.

Length of Writing Tests. The pre- and posttest writing assignments required students to describe a pet and a school event (see Appendix). They wrote on paper with no time limits. The same assignment was given at the beginning and end of the year, with 25 students available for the pre and posttest description of a pet, and 22 students available for both tests for description of an event. The mean length of the students' pretest essays were 48 and 65 words, and the mean length of the posttest essays was 106 and

84 words. There was a much greater increase in the length of the students' descriptions of their pets. However, individual variance is high. The median score on the description of a pet was 35 words for the pretest and 71 words for the posttest. The median for the description of the event was 54 words for the pretest and 72 words for the posttest.

Length of Classroom Writing Assignments. The classroom assignments represent a cross section of students' written work (on paper) which was collected by the teacher according to procedures previously explained. Each score represents the averaged length of papers written during the three month periods of Sep-Dec, Jan-Mar, and Apr-Jun. All students' papers for each topic were used resulting in slight differences in the number of papers in each period. Although there is a large range of individual differences, there is a steady increase in the means from 42 to 60 to 78 words.

The following essay is an example of a student's work at the beginning of the year. The assignment was to write an essay about "what you like to do on Saturday." The teacher lead a whole group "pre-writing" activity in which the students contributed ideas for essays. These ideas were listed on the blackboard and the students were then given time to write their essays. This essay is the same length (26 words) as the class average for this assignment. The spacing and errors are those of the student.

Denny Sept. 15, 1983

wach tv.
play go to the movies
skatboad play socer
ride my bike roller skat
play with my askshon figurs
go on a piknik whith my

In an essay at the end of the year, the students were asked to write about the meaning of the Olympics. The same pre-writing procedure preceded the writing of the essay. The essay written by this particular student is slightly longer (126 words) than the class average (105 words) for this assignment. Again it is typed as the student wrote it.

> Denny Paul Johnson 6-7-84
>
> The Olympic Dream
>
> Being famous is't everything as we learaned from Ted Duger yesterday afternoon in Los Angeless where they are holding the Olimpics. Well now I don't know weather you knew this or not but Ted told me something that was very interesting you have to go through alot of pain. Now alot of people think that the Olympic dream is to be fanous but it really is't the Olympic dream is to compeat and to have fun doing it.
>
> Now I would like to tell you a story when I was a kid the Olympics were being held in L.A. we were having an Olympics at are school I never won but I had fun doing it so it didn't matter. Of course thats the Olimpic dream to me.

The first essay was similar in length (as well as quality) to ones written by other classmates. This student provides no introduction to the essay and handed in the essay without completing the last idea. Except for the first period, there is no punctuation. It is an almost telegraphic message to the teacher which simply provides the minimal information necessary to answer the question that she posed: What do you do on Saturday?

The second essay has both an opening sentence and a final concluding sentence. While the student still makes both spelling and punctuation errors, there is much improvement over the earlier essay. He is able to express his ideas about the Olympics in a coherent way with only a slight problem with the time frame from the first to the last paragraph. These essays provide an example of the average increase in the ability of the students to express their ideas in writing over the year.

Length of Newspaper Articles. There were three editions of the Computer Chronicles Newspaper published in this classroom (Table 6). The stories in these newspapers are the results of pairs of students composing articles at the computer. The newspaper represent the students' selection of the best articles written by themselves and the other newswire reporters.

Newspaper edition dates:	Dec	Mar	June
Total number of stories:	25	35	18
Total in paragraph format:	19	30	17
Newswire stories (paragraph):	5	16	7
Local stories (paragraph):	14	14	10

Table 6: The number of stories in each of the editions of the newspapers that were in a format in which length was assessed.

The three editions of the newspapers contained 21, 35, and 18 articles respectively. A slightly smaller number had the appropriate form for a word count (19, 30 and 17). For the first edition, most of the stories were written by the students in the classroom, but the second and final editions carried a higher percent of stories that were written by other students and received on the newswire.

Notice that the length of these computer generated articles (Table 5) were about the same as the length of essays written on paper at roughly the same period. This means that the students who wrote these stories had mastered the technology of the computer sufficiently to write essays that were of similar length to those that the class wrote on paper.

Summary of Length of Essays. Examining the length of the students essays in this class over the year indicates a steady gain in the length of students' writing. Looking across the three types of writing assignments, the students essays at the beginning of the year were an average length of about 50 words. At the end of the year the students work was more likely to be about 80 words in length. This indicates an increase of approximately 30 words or 60% in the length of writing over the year.

Quality of Essays in BMS's Fourth Grade

The quality of students' pre and post test essays was scored using the holistic scoring procedures described in Grubb (1981); the other writing samples were scored using the modified holistic scoring procedure described earlier. The essays were scored on a 0 to 4 point scale (see Appendix) and the results are displayed in Table 7. Overall, it indicates steady improvement in the quality of students' work over the year.

Pet Desc.	Sep (pretest)	Jun (Posttest)
Mean:	X=2.00 (n=25)	X=2.32 (n=25)
SD:	(.79)	(.80)

Event Desc.	Sep (pretest)	Jun (posttest)
Mean:	X=1.86 (n=22)	X=2.54 (n=22)
SD	(.80)	(.94)

Classroom essays	Sep-Dec	Jan-Mar	Apr-Jun
Mean:	X=2.09 n=65	X=2.15 n=66	X=2.47 n=59
SD	(.70)	(.81)	(.75)

Newspaper articles	Feb	Mar	June
Mean:	X=2.58 n=14	X=2.64 n=14	X=3.10 n=10
SD	(.79)	(.84)	(.74)

Table 7: The mean holistic scores (0-4 point scale) for three types of writing tasks in BMS's fourth grade classroom.

Quality of Writing tests. In comparing the improvement on the pre and posttest essays, the students improved more on the description of an event (1.86 to 2.54) than they did on the description of the pet (2.00 to 2.32).

The following pair of essays is an example of the gain in the quality of student writing from pre- to posttest.

Carol B_____'s description of an event pretest:

10/13/83

The Field Trip

One day last year in Mrs. Burts class we went on a field trip we went to Cedar Lane Park. We played kickball and had a snack. People were running around laughing and playing. Mrs. Lockharts class and Mrs. Grahms class came to. Some people had to stay in the classroom because they didn't bring their permision slip back. Well we stayed there for 2 hours then we went back to the school right before lunch recess. Everyone who stayed at the class asked did you have a good time? We told them of course we did.

The End

Carol B_____'s description of an event posttest:

6/4/84

Balloon Liftoff

Here at Olive School for our first time we had a balloon Liftoff. They held it on Jan. 13 1984. It was beautiful. First before we started they sent heilium balloons to each and every class room. And when our class room "B-2" got their balloons we went to to field and sat down. Then we attached cards that had Olive School's adress on it. And we had to write a little note asking them to send this card and write were you live and you can write a little note please. And the they blew a whistle and we let all our balloons in the air it was so beautiful seeing all those colors. Some were bleu, some were green there were all kinds of beutiful colors. Weeks later we had open house and they announced the kids who got their card back. And some of the balloons went to Washington, New Mexico, and all other kinds of places. And they announced the winners for the balloons that went the farsest the winning people were, Kevin Dunne his went to Riverside and Thereasa Caywood hers went to New Mexico.

it was neat....

The End

Both essays were scored high relative to the rest of the class, however the difference between them is representative of many of the other sets. The first essay was scored as 3 and the second as 4 by all of the readers.

In the first essay Carol begins weakly with "One day last year" and finally gets to the topic of the sentence, and the essay, at the end of the poorly formed sentence. The topic "is a good response to the prompt" but was not "completely clear throughout the composition." After a few details of the picnic, she indicates who went on the picnic with a side sequence about students who were unable to go on the field trip. This discussion is an example of the "irrelevant story or explanation" that are sometimes present in stories that were scored 3. The story is clearly about a field trip and with the exception of these comments, the topic is carried through to the end. There was appropriate word choice, though "not particularly vivid" and there were "sufficient details to make the description clear." While the story could have been better written, the sentence structure problems and grammar errors were not numerous. Ending with a quote and the reply to it was a nice touch.

The second essay is, in some ways, similar to the first. It begins by introducing the event in time and space and ends with her evaluation of the event, "it was neat!". However in this essay the information is presented in much better detail and sequence. It has "a clear topic which is an appropriate response to the prompt and which is introduced at the beginning of the description" with "good organization, including an introduction and a conclusion." The description of the whistle blowing and the colors of the balloons are examples of the "sensory details" in the story. There may be some confusion of facts in the story. If "Washington" meant the state of Washington and Riverside referred to a community in California, then it is hard to see why one of the winners was Riverside. However, the story was easily scored as 4 using the grading rubric (Appendix).

Quality of Writing Assignments. The classroom writing assignments represent a range of different types of writing tasks. Despite the diversity, the quality of classroom work on paper shows a pattern of improvement that is similar to that of the pre- and post testing. The average score of 2.09 for the first period (Sep-Dec) is similar to the 2.00 scored on the description of a pet, and slightly higher than the 1.86 scored on the description of an event pre test. Similarly, the class average (2.47) on the writing assignments for the last period (Apr-Jun) is slightly lower than the scores for either posttest (2.32 and 2.54) given in June.

Quality of Newspaper Articles. The newspaper articles also improved in quality over the year at a similar rate. Each issue contained articles from different students or pairs of students on different topics. There is, however, one pair of articles from the beginning of the year that contain similar content and have one author in common. The mistakes are those made by the authors.

Article by Sharon B___ and Tim D__ for first edition of Computer Chronicles:

> Olives Crazy Day
>
> Olive school had a crazy dress-up day.
> We had it at Olive school on 11-23-83.
> We had it because people did not receive
> gold slips.
> People dress up crazy.
>
> By Sharon B____, age 8 and Tim
> D_____, Age 9

Article by Sharon B____ for the last edition of the Computer Chronicles:

> The Egg Drop
>
> On April 13, 1984 the fourth and fifth graders at Olive School had an Egg Drop. We did it to see how creative we could be. You could use anything not over 12 inches long, and you put a raw egg in it with any sort of padding. Then the teachers from the school threw it down from a classroom building and if your egg didn´t break you got a treat!
>
> By Sharon B____, age 9

There seems to be an attempt in both article to include information in response to the computer prompt to describe what happened, to whom, when, where and why. The first essay was given a holistic score of 2, the second one was scored as 4.

The essay written at the beginning of the year about Crazy Day has "a topic that is an adequate response to the prompt" in this case to write about something that happened at school, but there is "minimal development of the description" with "few details and "unclear organization". Sharon makes the assumptions that the reader will know what gold slips are and why they are given. Without this information, it is very difficult to understand the story.

In the second story, the writer was more successful at including the necessary details to make it possible for students from other schools to understand what took place. The essay has "a clear development of the description, with no irrelevant stories or explanations," with "specific, vivid word choice," and "good organization."

Over the year students had frequent discussions in editorial board meetings about what "students in Alaska" would or would not understand. They became increasingly more skilled at providing information that they had taken for granted when writing for the teacher or for a local audience.

Summary of Quality of Students' Writing. The quality of the students' writing in this classroom show steady increases over the year. The greatest improvement is in writing newspaper stories. The students rate of gain from the pre- to posttest description of an event (36%) represents the highest rate of change. The published newspaper stories written on the computer show the next highest gain (20%) followed by the gain on classroom assignments (18%) and the pre/posttest description of a pet (16%).

This ranking suggests that the functional writing environment created by the Computer Chronicle Newswire did have a positive influence on the students' writing ability. While we do not have a matched control classroom to compare this rate of improvement, standardized testing provides some evidence that the gains made by these students were much greater than what is expected in the one year period.

Standardized Tests of Language and Reading Skills

As mentioned earlier, the California Test of Basic Skills (CTBS) was given at the end of each school year. The results of this testing are shown in Table 8.

LANGUAGE	1983	1984	READING	1983	1984
Spelling			Vocabulary		
Grade level eq.	3.9	5.1	Grade level eq.	3.9	5.1
SD	(2.2)	(2.0)	SD	(3.8)	(1.4)
Mechanics			Comprehension		
Grade level eq.	4.0	6.9	Grade level eq.	3.9	5.8
SD	(1.6)	(2.5)	SD	(1.5)	(1.8)
Expression					
Grade level eq.	4.1	5.9			
SD	(1.4)	(2.6)			
TOTAL			TOTAL		
Grade level eq.	3.9	5.7	Grade level eq.	3.9	5.4
SD	(1.4)	(2.1)	SD	(1.2)	(1.5)

Table 8: The results of the California Test of Basic Skills (CTBS) standardized testing for BMS's fourth grade classroom (n=22), expressed in grade level equivalents, at the end of third grade (1983) and fourth grade (1984).

The scores in May 1983 indicate that the students were, on the average at grade level (expected 3.9) in almost all areas. When tested in May 1984, however, they were above average in all subtests of writing and reading. The students show the highest gain in language mechanics (2.9 years) with high gains in the language expression (1.8 years) and reading comprehension (1.9 years) scores.

The dramatic increase of almost three years in language mechanics and almost two years in language expression and reading comprehension suggests that the functional learning environment created in this classroom was successful in teaching language art skills. Language mechanics taught in the context of students' writing and the process of peer review appears to be very effective strategies for helping students learn to write. Reading stories written by their peers in distant locations, as well as reading to interact with the computer, seem to have had a favorable effect on their reading ability as measured by this achievement test. The overall gains in the Language skills are represented in Figure 12.

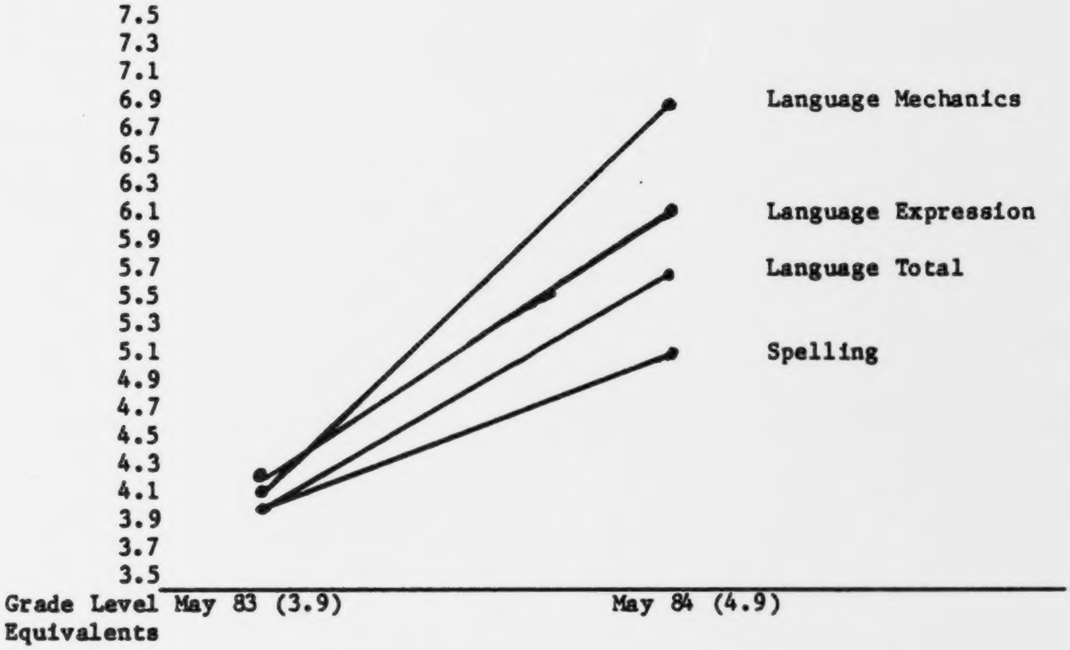


Figure 12: Comparison of grade level equivalent scores on the language portion of the California Test of Basic Skills at two times, May 1983 and May 1984 for the students (n=22) in BMS's fourth grade classroom.

Past research has pointed to the effectiveness of teaching language mechanics in the context of student writing rather than in grammar exercises (Strom, 1960). However in this classrooms students were editing the work of their peers as well as receiving feedback on their own writing. The following comparison suggests that editing the writing of other students may be one of the crucial factors that leads to improved writing skills.

While most of the students in this classroom wrote stories for a newspaper and national news network, a smaller number of students participated in "editorial boards" described earlier. These students were exposed to a wide range of writing skills and language problems. Collectively they formed evaluative frameworks which could then serve to guide their own writing.

If serving on an editorial board was a vital part of the learning experience that lead to the improvement in the language art skills, then we would expect the students who served on an editorial board to score higher then the class average who did not have this experience. The students selected for the first board should show the greatest gains since they had the longest period after this experience to improve their writing. The students serving on the first editorial board were selected randomly from the 2/3 of the students who volunteered for this position.

Table 9 shows that in May of 83 the scores of the four students who made up the first editorial board were very similar to the class means in the language portion of the CTBS with the exception of a slightly higher score for language expression.

	1983	1984		1983	1984
Spelling			Mechanics		
Class Mean (n=22)	3.8	5.1	Class Mean	3.9	6.8
SD	(2.2)	(2.0)	SD	(1.6)	(2.5)
Edit. Board (n=4)	3.8	5.0	Edit. Board	3.9	8.6
SD	(0.7)	(0.6)	SD	(1.4)	(1.2)
Expression			Language TOTAL		
Class Mean (n=22)	4.1	5.9	Class Mean	3.9	5.7
SD	(1.4)	(2.6)	SD	(1.4	(2.1)
Edit. Board (n=4)	5.1	6.3	Editorial Board	4.1	6.1
n=4	(1.7)	(1.4) n=4	SD	(0.7	(0.8)

Table 9: Comparison of test scores on the California Test of Basic Skills for the fourth grade class with the members of the first Computer Chronicles editorial board.

Again the difference that is striking is the increase in language mechanics.

The students gained over 4 grade levels in this area. Figure 12 shows the gain for these students from September to June.

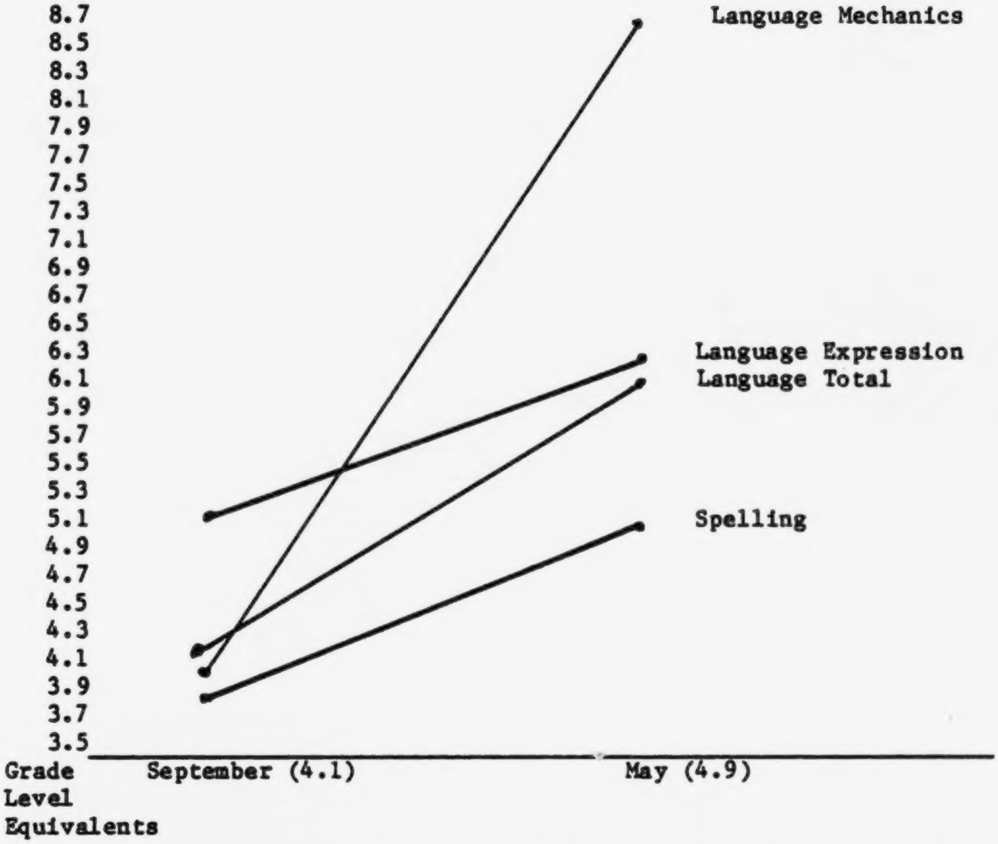


Figure 13: Comparison of grade level equivalent scores on the language portion of the California Test of Basic Skills at two times, May 1983 and May 1984 for the students (n=4) randomly selected to be members of the first editorial board in BMS's fourth grade classroom.

Figure 13 is very similar to figure one with the exception that the language mechanics shows an increase of 4.5 grade levels. This finding suggests that it is not only the correction of one's own errors in the context of writing, but perhaps even more important, the evaluation of the writing of others that leads to gains in the mechanics of writing. The process of peer review may be a valuable resource for helping students learn to write.

Conclusion

Standardized and project testing and classroom work all point to the same conclusion. The students in this fourth grade classroom learned a great deal about language as an art. They were able to master the use of a new form of technology for writing and do so while improving their writing and reading skills beyond their grade level expectation. The evidence from this classroom indicates that a skilled language arts teacher with some prior computer experience can use the computer to create functional learning environments for students that are very effective for teaching language arts skills to fourth grade students.

In the other project classrooms, some but not all of these features were present. In the following classrooms, the focus will be on the how the presence or absence of some of these features resulted in similar or different patterns. Each of the classrooms provides another perspective on the way computers can be integrated into the learning process.

Description of Writing in KW's Fifth-sixth Grade

KW and BMS shared a similar educational history which is reflected in the organization of their classrooms, general teaching strategies (chapter two) and approaches for teaching writing. Most of KW's teaching experience had been in upper elementary grades, however this was her first experience teaching a "GATE" (Gifted and Talented Education) classroom.

KW had minimal knowledge of computers prior to the project. She had taken some courses designed to help teachers review software, but had little experience using a computer and described herself as somewhat computer phobic. The software that was used on the project was new to her and she learned how to use it her students.

KW encouraged her students to try to work independently and to try to solve their problems themselves. If that failed designated "peer computer experts" were to serve as resources. KW used the same strategy in developing her own computer skills. She explored a number of possible solutions to a problem and then, if unsuccessful, she called on member of the research staff for advice. She once refused a researcher's offer to solve a software problem, arguing that teachers do not routinely have that type of support. She chose to delay the introduction of the new software until she was able to make the necessary changes herself.

KW and BMS taught writing as a process in much the same way except that in KW's classroom the whole class was less likely to participate in the pre-writing phase as a whole group. Instead, students were encouraged to individually generate ideas, organize them and plan their essays prior to writing. Students were required to write often with increasing length requirements to encourage writing fluency.

The initial computer activities were directed toward helping students master the hardware and software procedures. The major writing activity at the computer center was composing newspaper articles. Beginning in January, the students wrote or edited newspaper stories for 3 weeks. Then, while an editorial board assumed the task of evaluating and assembling the newspaper, the rest of the students worked on some other writing task on the computer, including computer-pal letters and a variety of interactive reading and writing programs.

All students in this classroom wrote one or more articles for the class newspaper; each of the four editions of the newspaper carried articles from over half the class. Most the students had the opportunity to serve on an editorial board. Members of the editorial boards for each edition were selected from those that wanted to participate (over 3/4 of the class) by KW. She made the selections to ensure even numbers of boys and girls, of 5th and 6th graders and a mix of skill levels.

Length of Student's Writing

The length of pre and posttest essays, classroom assignments and computer newspaper stories are displayed in Table 10.

Pet Desc.	Sep (pretest)	Jun (Posttest)
Mean:	X=74 (n=23)	X=108 (n=23)
SD:	(31)	(44)

Event Desc.	Sep (pretest)	Jun (posttest)
Mean:	X=71 (n=25)	X=91 (n=25)
SD	(25)	(32)

Classroom essays	Sep-Dec	Jan-Mar	Apr-Jun
Mean:	X=95 n=83	X=179 n=60	X=207 n=121
SD	(38)	(63)	(59)

Newspaper articles	Feb	Mar	June	
Mean:	X=104	X=64	X=91	X=82
SD	(37)	(29)	(39)	(27)
	n=21	n=16	n=9	n=13

Table 10: The mean length of three types of writing assignments from September to June in KW's classroom.

Length of Writing Tests. There were 23 students who were available for both the pre and posttest descriptions of pets and 25 for the description of a school event. The pretest scores indicate that the length of students' essays were, on the average, about 74 words when describing a pet and 74 words when describing an event. At the end of the year the students' essays were 108 words for the pet description and 91 words for the event description. The increase in the length of the essays is very similar to the pattern in BMS's classroom.

Length of Classroom Writing Assignments. Writing assignments were collected from the students at the beginning of the year, at roughly monthly intervals and at the end of the year. Table 10 shows the average length of these different sets of papers. The increase in the length of students' writing in this classroom was influenced by the teacher's minimal length requirements. The teacher set a higher standard as time went on "to encourage both fluency and extension of expression," to "stretch" their writing skills. The teacher began to set minimum length in November at 125 words and increased the requirement by 25 words about every 6 weeks. At the end of the year the minimum was set at 250 words. While the students did not all meet this requirement, this strategy did seem to be effective in increasing the length of the students' writing. It will be important to see if this increase in length was accompanied by an increase in the quality of their writing.

Length of Newspaper Articles. The teacher had planned to publish a monthly newspaper each month beginning in January. It took the editorial boards longer to make their decisions and edit the stories then she originally expected, however, and a total of four were produced, one in February, one in March, and two in June. The increasing number of stories received over the newswire from other classrooms extended the editorial board's deliberations for the last two editorial boards to the end of the year; the number of newswire stories accepted increased dramatically (see Table 11).

Newspaper edition dates:	Feb	Mar	June	June
Total number of stories:	27	31	24	53
Total in paragraph format:	22	20	20	50
Newswire stories (paragraph):	1	4	11	37
Local stories (paragraph):	21	16	9	13

Table 11: The number of stories in each of the editions of the newspapers that were in a format in which length was assessed.

The mean length of the stories on the first edition of the newspaper (105 words) was longer than that of any of following editions. Almost all of the stories in the first edition were not composed at the computer. These stories were written by individual students on paper before they learned how to use the software. They were typed into the computer as an early exercise in learning how to use the computer. The stories for the second edition were composed at the keyboard by pairs of students and the mean length of these stories dropped to 64 words, which is lower than the mean of students' individual writing off the computer. The articles in the last two editions of the newspaper (91 and 82 words) show a rate of increase that is similar to the articles produced in BMS's class.

The mean length of these articles is only slightly less than the mean length of the newspaper articles written on paper with pencil at the end of the year (91 words). This comparison indicates that the students who wrote these newspaper articles were able to compose articles on the computer and within the social and time constraints of the computer sessions that were similar in length to the posttest stories written on paper individually with no time limits. In doing so, they demonstrated their ability to master a new writing technology and to develop collaborative writing strategies at the same time as learning to extend the length of their writing on a given topic.

Summary of Length of Student's Essays. The students in KW's class show steady pattern of increase in the length of their writing across the year. The increase in the length of classroom essays written on paper were clearly influenced by the minimum length requirements established by KW. The similarity between the lengths of the posttest news essays written on paper and the newspaper articles at the end of the year composed on the computer suggests that the students were able use the computer effectively for their writing.

Quality of Writing in KW's Classroom

The pre- and posttest essays quality measures of classroom assignments and computer newspaper stories are displayed in Table 13. Assessing improvement in the quality of writing in this classroom is made more difficult by a ceiling effect in most of the measures.

Pet Desc.	Sep (pretest)				Jun (Posttest)
Mean:	X=3.05 (n=23)				X=3.20 (n=23)
SD:	(.66)				(.68)
Event Desc.	Sep (pretest)				Jun (posttest)
Mean:	X=2.40 (n=25)				X=3.43 (n=25)
SD	(1.27)				(.60)
Classroom essays	Sep-Dec	Jan-Mar		Apr-Jun	
Mean:	X=2.70 n=83	X=3.41 n=60		X=3.47 n=121	
SD	(.92)	(.69)		(.63)	
Newspaper articles		Feb	Mar	Jun	Jun
Mean:		X=3.42	X=3.66	X=3.12	X=3.42
SD		(.51)	(.62)	(.64)	(.67)
		n=9	n=16	n=9	n=13

Table 12: The mean holistic scores (0-4 point scale) for three types of writing assignments from September to June in KW's classroom.

Quality of Writing Tests. The students in this classrooms, like those in the other project classrooms, wrote better essays at the beginning of the year about a pet rather than a school event. The lower initial scores in the description of an event suggest that students were not as skilled in this type of writing task. There was, however, more improvement in the students' description of a school event at the end of the year than in the pet descriptions. The students' participation in the newspaper writing activities is likely to be partially responsible for the difference but there is also likely to be a ceiling effect of the initially higher pretest scores for the description of a pet pretest.

The following set of papers is an example of one student´s pre and posttest descriptions of a pet that scored lower than the class average. The pretest was a description of a horse and was written like this:

> Mary
>
> I got a pet to today it´s a horse.
> it´s white all over and it´s a stallion.
> and it wineis. and it feels like silk
> and velvit. I think all ride all
> over the country.

The posttest for this student is a description of a unicorn. (Some students asked,and were given permission to describe an imaginary animal by KW). This is how the second essay looked:

> Mary H ________
>
> My Pet
>
> My mom got me a pet
> today. it is a unicorn. he is real
> big, it is so big that it is
> nine feet tall (on four legs). he
> is pure white except for its
> horn. it is pure gold. it is a
> beutiful unicorn. my unicorn
> snorts and grumbles and sometimes
> purrs or wines. he feels like
> silk or velvet. My pet looks
> manifucent after he is brushed
> and his hair is washed. his name
> is Maltia Mikea. he is a
> beutiful animal.
>
> the end.

The pretest for this students received a holistic score of 2 by the three readers. This indicates an adequate essay. It has "a topic which is an adequate response to the prompt" yet it has "minimal development of the description" with "few details." There are "many errors in the use of punctuation marks, capital letters, and spelling" and "incorrect or inappropriate structure in many sentences."

The posttest essay shows clear improvement over the pretest. It has "a topic which is a good response to the prompt" and has "good organization." While it has "specific, vivid word choice" and a brief "introduction and conclusion," features of an excellent essay (4 points), it also has "many errors in the use of punctuation marks, capitals letters, and spelling" and "incorrect structure in many sentences," features of a adequate response (2 points). Since most of the characteristics fall in the category of a good composition (3 points) with some falling in the excellent (4 points) and some in an adequate category, the holistic score given by the three readers was 3.

Both the pre and posttest scores of this student were below the class norm, with a higher rate of improvement. The average student pretest was similar in quality to this second essay. While in most cases there was improvement in some features of the description, they were often not sufficient for it to be scored as an excellent essay. The use of a six or eight point scale rubric would have been necessary to show these changes.

Quality of Classroom Writing Assignments. The students classroom work shows a steady improvement in quality over the year. During the first the months, the average holistic score of the essays was 2.70, during the second period it increased to 3.41 and during the last period it was 3.47. Again there is likely to be a ceiling effect for the gain in the last period. What is of particular importance is that the gains in length that were pushed by minimal length requirements were accompanied by corresponding increases in the quality of students writing.

The following two stories by one students indicate the average gain in quality from the beginning of the year to the end of the year. Both stories are "stickers stories", stories that are inspired by the illustrations on stickers that students select.

Sticker story, October 5, : Sticker shows three brightly colored helium ballons

The Rainbow Ballons
One Day I won 3 helimun Ballons
I was so excited. I asked my friends,
Collem and Monica if they would like to
ride in one each. The both said Yes and
I said to bring a friend. I decied to
ask my best friend Tiva to ride with
me.
The next day I packed three
big lunches. My friends arrived at
noon. First came Collen. "This is
my friend Vivian." She said. Then Monica
"I would like you to meet Brandy."
They each brought "an animal. Collem
broght a monkey named krakers.
Monica brought her cat named
Sugar Pie. I had my Dog named Bets.
I let Monica and Brandy have the
have the red one. Collem wanted the
Blue one. So I got the green and yellow
one. We stared off at one o´clock We
floted around for along time. Everyone
on the ground called us the Rainbow
Ballons. Finnally we landed at 5´o´clock.
My friends said it was fun. That´s
the story of the Rainbow Ballons.

Sticker story, April 8, : Four stickers, one of blond woman, a rose, a butterfly and a unicorn in front of a rainbow looking into a blue pond with blue clouds.

BLUE MIST

By Robin T_____

There once was a young princess who had a very large imagination. The funny thing was that whatever she imagined came true. One day she was sitting in her rose garden. (She loved roses.) She started imageing a unicorn drinking from a crstal clear pond and behind the unicorn there was rainbow. Then a voice started calling her. She looked up and saw a butterfly. "Ivinnia! Ivinnia!!" it said. "Oh, sorry." She said. "It is just I always get involved in my day dreams. I always wonder were it is going to show up! "Ivinnia," the butterfly said "they are going to disappear. That is all of them except 3." "What do you mean?" asked the startled girl. "I mean your time is up." replied the butterfly. "So what 3 is it going to be?" She just sat there thinking for a minute. "I have a question." said Ivinnia. "Can I have a new one?" "Sure." Said the butterfly. "Only if you have a good reason." "Well began Ivinnia "My first wish is I want a rose. The most beautiful rose in the universe. I also want you to keep me company." "Your wishes are my command." he said. "And last but least" said Ivinnia "I want the unicorn picture. "Follow me!" said the butterfly and she did. While she walked everything started disapering. At the end of the path there her wishes were. She started running. Her heart was filled with joy. All around her there was a blue mist. She ran, picked up the flower and jumped on the unicorn. Calling the butterfly she took off into the blue mist. She ended up calling the unicorn blue mist.

The first story was scored as a good composition according to a four point rubric for narrative writing (see Appendix). It has a "sequence of events which is a good response to the writing prompt" in this case the picture. While there is "good development of the story" it is "marred by an irrelevant description" of the pets that were taken in the balloons. There is a clear temporal "organization of the story" and "good word choice, which is, however not particularly fresh or vivid" and includes "some errors in the use of punctuation marks...and spelling".

The second essay indicates real development in the students' control of a number of narrative conventions. It was scored as an excellent composition according the the four point rubric for narrative writing. Its strong features are a "fresh and vigorous word choice," "a variety of interesting details," and a "clear sequence of events which is an appropriate response to the prompt and is introduced at the beginning of the composition." It has correct and appropriate structure in almost all sentences" and very few errors "in the use of punctuation marks, capital letters, and spelling."

The first essay is very similar in quality to those written by the other students in the class. The increase in quality between this early essay and one written in April is similar to that of many of the other students in the classroom. The quality of students' work in this classroom increased dramatically between the first and second periods and then, possible because of individual differences and a ceiling effect, the rate of increase becomes much more gradual.

Quality of Newspaper Articles. The stories accepted for the newspaper began at a relatively high level of quality with small changes across the issues. It is likely that this pattern is the result of a ceiling effect. The mean score for the articles in each issue were: first issue 3.42 (n=22), second issue 3.66 (n=16), third issue 3.12 (n=9) and final issue 3.42 (n=12).

The stories for the first edition were composed on paper and typed into the computer. The stories for the second edition were composed on the computer by pairs of students writing together. They were, on the average, shorter (64 words) than any other of the writing samples written either on or off the the computer. They are also, on the average, better written (3.66 points) than any of the writing samples.

During this time, KW noticed that students' collaborative essays on the computer were much shorter than essays written by students working alone off the computer. She also noticed that the students working together at the computer were spending time discussing their writing. She suspected that the students were spending more time editing and revising their work and that the shorter length might be offset by higher quality of the writing. (Papers had not been scored at this point).

Interested in the effect of collaborative writing on length and quality of essays, she assigned pairs of students the task of cooperatively writing a newspaper story using a single sheet of paper to compare with the stories pairs of students wrote using the computer writing tools. Unfortunately, the same pairs of students were not assigned to each of the conditions. Therefore, we compared the length and quality of the cooperative stories written on paper (n=14 essays) with a set of newspaper articles written by pairs of students working on the computer during the same week (n=9).

There was no difference in length between the two sets of papers. The mean length for stories written collaboratively on paper was 81 words, and the mean length of stories written collaboratively on the computer was 80 words. The quality of the paper/pencil was similar to the computer sample;

the holistic score was 3.7 for paper/pen essays and 3.6 for computer essays . No writing sample on paper was scored higher than 3.7 and the average writing sample for this time of year was 3.5.

Students' collaborative essays either written on paper or on the computer were shorter but of higher quality than individual essays. Students seem to be doing more than composing a first draft when they write collaboratively. The immediate feedback from the other person helped clarify ideas as essays were being written, resulting in more revising and editing than when they worked alone. This suggests collaborative writing that is facilitated by the computer may be a important factor in the gains in quality of writing that were evident in these classrooms over the school year. Collaborative work, facilitated by the computer, may be an important way to maximize students' learning.

Summary of Quality of Writing. Writing pre- and posttests show a dramatic increase in the quality of students descriptions of events. The higher scores on the pretest description of pets suggests a ceiling effect. There was a steady increase in quality of the students classroom assignments that parallels the increases in length. The cooperative writing of newspaper articles at the computer resulted in shorter articles of higher quality. It is likely the collaborative writing is one of the important dimensions responsible for the increases in the quality of student work over the year.

Standardized Tests of Basic Skills. In this fifth-sixth classroom, only the fifth graders were given the California Test of Basic Skills at the end of the year. About a third (6 of 17) of the fifth graders had reached the test score ceiling (10.9) at the beginning of the year. Another 4 reached the ceiling some time during the year. The 7 remaining students ranged from one student that showed no change to a student with a gain of three years. The small number of students and the large variation makes it impossible to use standardized testing as an indication of student gain in this classroom.

Conclusion. The teacher in this classroom, KW, was experienced in teaching writing but was a novice in terms of computer use. She was working with upper-grade talented students. She had little difficulty in extending her teaching strategies to include the computer as one of many work stations in her classroom. The students were able to use the computer tools to extend their writing skills. It was difficult to assess the increase of students skills in this classroom because of a strong ceiling effect. This effect was evident in the project testing, evaluation of student's writing and in standardized testing by the school district. Even with the ceiling effect, the students in this classroom showed gains in writing that were similar to those of the students in BMS's classroom. The role of peer review in collaborative writing was again pointed to as the one of the significant aspects responsible for improvement in writing skills.

Description of Writing in BL's Third-fourth Grade

BL is a bilingual teacher with previous experience in teaching upper grade students. This was her first teaching experience with younger students. Prior to the study, she had no special training in the area of language arts instruction, minimal experience with computers and was unfamiliar with the software used on the project.

BL's school had a rotation procedure which regrouped students homogeneously according to skill level for math and reading. In this arrangement, the third and fourth grade students with the lowest achievement scores in reading were grouped in her classroom for language arts. This group also included a large number of Limited English Proficient (LEP) students. The students in BL's classroom for reading and writing were reading at the first or second grade level in either Spanish or English as measured by the California Test of Basic Skills.

At the beginning of the year there was no printer in BL's classroom. The students saved their stories on disk to be printed out later using a printer located in another classroom. In mid-January a printer was provided for the classroom.

As in the other classrooms, the first computer activities (Typing Tutor and Apple Presents Apple) were designed to give the students some familiarity with the keyboard. The students then worked with some interactive story programs that helped the students make their own stories without having to write text. In November the students were introduced to writing Computer Chronicle stories with a choice of working in either English or Spanish. The students with low reading levels had trouble understanding the writing instructions and some found the task too difficult.

BL decided to switch to interactive programs that required less writing by the students while she explored ways to provide social support for writing on the computer. In February the students resumed writing newspaper articles along with the other computer activities with the help of peer tutors or bilingual computer coaches. The teacher used a number of different interactive tools trying to find the necessary match between the skills of the students and the level of the programs. While students enjoyed many of these programs, BL wanted to be able to integrate the computer with other classroom activities.

As her own skill with the computer software increased, she decided to use the interactive system (ITI) to write her own activities. After a few hours of training, she wrote two computer programs to use with her students. One was a prompt to help students write friendly letters and the other was a book report form. In both cases she wrote English and Spanish versions. These computer activities were introduced in the last two months of school and were integrated with other activities that occurred in the classroom.

Length of Students´ Essays in BL´s Class

The length of students´ essays over the year show a steady increase in length (Table 13). While these students began the year with skills that were much lower than the classrooms discussed so far, their rate of improvement is very similar to these other students.

Pet Desc.	Sep (pretest)		Jun (posttest)
Mean:	X=47 (n=15)		X=69 (n=15)
SD	(21)		(32)
Event Desc.	Sep (pretest)		Jun (posttest)
Mean:	X=59 (n=14)		X=71 (n=14)
SD:	(33)		(41)
Classroom essays	Sep-Dec	Jan-Mar	Apr-Jun
Mean:	X=38 n=24	X=45 n=33	X=68 n=21
SD	(20)	(24)	(28)
Newspaper articles			June
Mean:			X=52 n=32
SD			(28)

Table 13: The mean length of three types of writing assignments from September to June in BL's classroom.

Length of Writing Tests. Like the students from the other classrooms, the students in BL's classroom wrote slightly longer essays describing a school event than they did when describing an animal. The mean length of the posttest was almost the same for both of the topics. This means that the gain in length for the description of a pet was greater than that for an event, as it was for each of the previously discussed groups of students.

Length of Classroom Writing Assignments. The mean length reported for classroom essays for each of the three periods represents the work of the low achieving monolingual students. Most of the writing in this classroom was done during the period of the day in which students were grouped based on reading levels. Often the bilingual students who were in BL's classroom for this period worked with a bilingual aide on reading skills. Therefore, they were not present for many of the writing activities.

The average length of students' work in the first three months of school (38 words) was shorter than the average length of either of the pretests (47 and 59 words). The length of work during this first period was also only slightly shorter than that of the fourth graders in BMS's class for this same time period(42 words).

The pattern of gain in the length of essays over the year is different in this classroom than the previously described classrooms. In BMS's and KW's class the greatest gain was made between the first and the second trimester. In BL's classroom the increase in the length of students' writing is much greater between the second and third period than it was during the first and second. This early period is when BL had difficulty finding appropriate computer activities for her students. The low reading level and the special need for bilingual software slowed down the integration of the computer in this classroom. It was not until the latter part of the year that the students in BL's classroom were using the writing tools productively. It is possible that the students longer essays in the later part of the year were influenced by more successful writing experiences on the computer.

One way to assess the gains made by these students at the end of the year is to compare the length of their essays written at the end of the year to the older students essays written at the beginning of the year. The posttests of the low achieving third-fourth graders in BL's class (68, 71) were very similar to the length of the pretest of the Gifted and Talented (GATE) fifth-sixth graders in KW's class (70,74). This suggests that these students showed gains in writing fluency that were greater than expected given their age and academic history.

Length of Newspaper Articles. There was one newspaper published in June which contained a sample of stories written across the whole year. This means that it is not possible to use published newspapers as a means to assess increases in length of writing on the computer over the year. The single edition included 32 stories written by 22 of BL's students.

Summary of Length of Writing. The gains in length of essays in this classroom are impressive given that this was a homogeneous group of the lowest skilled third and fourth graders in the school. Given the difficulties that these students had in reading and therefore in the use of the software, it would not have been surprising to see little or no growth in the length of their writing. In fact, the gains in length seemed to increase more towards the end of the year at the same time as use of the computer were more successfully integrated with the curriculum.

To evaluate their improvement, a comparison was made between the length of posttest essays of these low achieving students with the pre-test scores of the older fifth-sixth grade gifted students. There was almost no difference. This suggests that these students made gains in their writing that are beyond what is normally expected.

Quality of Students' Writing in BL's Classroom

The holistic scores for each of the three types of writing assignments are displayed in Table 14.

Pet Desc.	Sep (pretest)			Jun (Posttest)
Mean:	X=2.13 (n=15)			X=2.44 (n=15)
SD:	(.68)			(.57)
Event Desc.	Sep (pretest)			Jun (posttest)
Mean:	X=1.83 (n=14)			X=2.17 (n=14)
SD	(.98)			(.80)
Classroom essays	Sep-Dec	Jan-Mar	Apr-Jun	
Mean:	X=2.04 n=24	X=1.81 n=33	X=2.29 n=21	
SD	(.46)	(.74)	(.69)	
Newspaper articles				June
Mean:				X=2.85 n=30
SD				(.83)

Table 14: The mean holistic scores (0-4) for three types of writing assignments from September to June in BL's classroom.

Quality of Writing Tests. BL's class was the only class in which the rate of improvement on the two different writing tests was similar. The improvement in the quality of the posttest essays describing a pet (an average gain of .31 points on a 0-4 point scale) was almost identical to the improvement in the posttest essays describing an event (average gain of .33 points). However in the other classrooms the increase in quality of the posttest description of an event was more than twice as great as the increase in quality of the posttest description of a pet. (In BMS's class the increase in quality of the posttest test essays for descriptions of a pet averaged .32 points, while the increase in quality of the posttest descriptions of an event averaged .79 points.)

The pre- and posttests were designed to assess increases in a type of writing activity (newspaper writing) that was frequently done on the computer in these classrooms. For reasons already discussed, this classrooms involvement in writing newspaper articles on the computer was minimal. It is possible that if these students had been given pre and posttests writing tasks that reflected their use of the computer (for example in writing book reports or letter writing), their rate of improvement would be proportionally higher.

Quality of Classroom Writing Assignments. The students' writing on paper did not show much improvement in quality between the first and second period. The average holistic score for the 24 essays collected during the first period was 2.04; the score for the 33 essays collected during the second period dropped slightly to 1.81. From the second to the third period however, there was a gain of a half point on a 0-4 point scale. This is the same period in which the students' work showed a gain in length. These findings suggest that the more successful uses of the computer introduced by BL toward the end of the year had an influence on the quality as well as the length of students' writing during this period.

Quality of Newspaper Articles. The quality of the students work published in the single edition of the newspaper represents a collection of the students' best work over the year. Since the stories were written throughout the year it was not possible to determine improvement over time by using this newspaper. The students engaged in a range of activities on the computer across the year but it is very difficult to compare them because there were varying amounts of help provided by the software and social support for writing was not consistent across the computer activities.

Summary of Quality of Students' Essays. The rate of improvement in the quality of the students work in this classroom was very similar to that of the students in BMS's classroom. The pretests and early classroom work from these two classrooms was similar to the older fourth graders scoring slightly higher than the third and fourth graders in BL class. The rate of gain in the two classrooms is similar for the description of a pet and for the classroom assignments. However, unlike any of the other classrooms, there was no higher rate of improvement for the description of an event test. Newspaper writing did not play a central role in this classroom and the rate of improvement for this type of writing is no different than for other types.

Conclusion. This classroom showed a unique pattern of student improvement. In BMS's and KW's classrooms the computer was successfuly integrated into the curriculum at the beginning of the year and the rate of improvement over the year was steady. In BL's classroom, it was necessary to make adjustments to the software and to the way it was used with students. The integration of the computer activities into the curriculum towards the end of the school year were accompanied by a higher rate of increase in the quality and length of students' writing.

An important dimension in this case study was the growth of the teacher's knowledge as well as that of the students. BL was teaching at a new grade level, learning a new method for teaching writing as a process, and learning how to use a computer and a software system. All of her students were low achieving and in some cases limited English proficient. While any one of these factors alone could make her adjustment to this teaching situation difficult, she was also faced with difficulties in the skill level of the activities was not always appropriate for her students.

Despite there constraints, her students showed a substantial rate of improvement. Furthermore, she was the only teacher who used the authoring capacity of the computer system to create new software during the course of the year. Because of the skill level of her students, and the additional needs of bilingual students, BL was forced to take the most active role in finding a way to integrate the computer with her teaching objectives. BL's mastery over the system to create new computer tools for her students was very impressive.

Description of Writing in KO's Fifth-Sixth Grade

KO is a teacher with a great deal of expertise in teaching upper grade students how to write. KW's and KO's approach is very similar. Previous to this study, these teachers had worked at the same school sharing teaching materials and strategies for language arts instruction. It was this similarity in approaches to language arts instruction and similar grade level assignments that led us to select this classroom as a control.

Unfortunately, the students assigned to these two classrooms were not similar. The students assigned to KO's class were below average grade level at the beginning of the year as measured by the California Test of Basic Skills. The students in KW classroom were at the other end of the educational spectrum-functioning well above grade level. The students in KO's class are similar in age to the fifth-sixth graders in KW's class, similar in grade level achievement to the fourth grade students in BMS's class and similar in educational history to the low achieving students in BL's class. Because of these differences, this classroom can not in any strict sense be considered a control group for any of the classrooms. However many of the comparisons highlight differences that may be important in the overall assessment of the effectiveness of the computer facilitated learning environments.

As in KW´s and BMS´s classrooms, KO arranged her classroom around learning centers. The low scores on vocabulary and spelling subtests of the California Test of Basic Skills prompted her to focus on these areas of skill development. She created an individualized spelling program for each student integrated with the writing process to promote vocabulary development.

About one third of the students in KO´s class participated with students from other classrooms in the production of four newspapers over the course of the year. KO held weekly editorial board meetings during lunch for the fifth-sixth grade students who wanted to be involved. During these meetings assignments were given which were often completed during regular classroom writing periods. After the stories were written and edited, the students blocked them letter by letter on graph paper and then they were typed by the teacher.

Length of Students´ Essays in KO´s Fifth-Sixth Grade

The length of students´ writing in this classroom are shown in Table 15. Unlike the other classrooms, there is no clear pattern of improvement over the school year.

Pet Desc.	Sep (pretest)	Jun (posttest)
Mean:	X=73 (n=21)	X=70 (n=21)
SD:	(63)	(30)

Event Desc.	Sep (pretest)	Jun (posttest)
Mean:	X=109 (n=21)	X=56 (n=21)
SD	(56)	(23)

Classroom essays	Sep-Dec	Jan-Mar	Apr-Jun
Mean:	X=58 n=50	X=78 n=73	X=65 n=30
SD	(22)	(36)	(25)

Newspaper articles	Nov	Dec	Feb
Mean:	X=65 n=3	X=72 n=5	X=69 n=5
SD	(21)	(14)	(19)

Table 15 : The mean length of three types of writing assignments from September to June in KO's Classroom.

Length of Writing Tests. In both of the writing tasks the students pretests were longer than the posttests. In fact the mean length of one of the pretests, the description of an event, is 50% longer than the posttest and most other sets of papers written over the year. When the length of this pretest is considered in the context of the other writing done by these students, it it clear that these essays were unusually long.

The students in this classroom, as in the other classrooms, wrote longer posttest essays on the description of pets (mean = 70 words) than they did on the description of events (mean = 56 words). There was, however, a decrease instead of an increase from pre- to posttest for both writing tasks. While the change in length of the pre- and posttests describing a pet were almost the same length (73 compared to 70 words), individual variation over the year decreased. In all the other classes the variation increased with increasing scores. The move toward the group mean may point to an effect of homogeneous grouping of students on the achievement motivation of students.

Length of Classroom Writing Assignments. The drop in average length from the pre- to the posttest essays would be difficult to interpret without the context of classroom writing assignments. It is not likely that the student's writing decreased over time. By comparing the lengths of the pretest essays (73 and 109 words) to the students classroom writing at the beginning of the year (58 words), we can see that these essays were on the average longer than their other written work.

Length of Newspaper Articles. Some of the students in KO's class participated, with students from other classrooms, in the newspaper writing project directed by their teacher. This writing was not done on the computer but provides for a comparison of a similar activity accomplished with the resources provided by the computer and printer.

Newspaper edition dates:	Nov	Dec	Feb
Total number of stories	28	27	22
Total in paragraph format:	7	6	6
Written by other students	4	1	1
Written by KO's students	3	5	5

Table 16: The number of stories in each of the editions of the newspapers that were written by students in KO's class and in a format appropriate for length assessment.

As can be seen Table 16 the newspapers produced were largely composed of entries that were not in paragraph form, making it difficult to compare lengths. (Other articles were lists of responses to questionnaires or surveys, puzzles, or birthday lists.) In the three issues of their newspaper there was an average of 25 articles representing contributions from about a third of her class. However only 12 of these contributions were in paragraph format and they were written by 5 students. As was seen in Table 15 there was little variation in the length of articles across the three issues (mean lengths of 65 (SD=21), 72 (SD=14), and 69 (SD=19).

Summary of the Length of Students' Essays. While there was some change in the average length of students' writing in this classroom, it did not present the same pattern of steady improvement that was evident in each of the other project classrooms. The average length of students' writing over the year showed only slight increases with individual variation decreasing.

The classroom writing samples do not suggest a gradual increase over the year but rather a high point mid-year with length of writing decreasing towards the end of the year. At the beginning of the year, the average length of students' writing in KO's classroom (58 words) was longer than that of BMS's fourth graders (42 words) and BL's third-fourth graders (38 words) but not as long as that of the fifth and sixth graders in KW's class (95 words). This ranking is consistent with expectations based on grade level and achievement scores.

At the end of the year, however, the ranking had changed. In all the other classrooms the average length of essays had more than doubled over the year. In fact, the average length of the essays by the low achieving third and fourth graders in BL's classroom (68 words) were longer than those of the fifth-sixth graders in this classroom (65 words). The contrast between the increase in length of students' writing in the three "experimental" classrooms and that of this control "classroom" suggests that the computer facilitated writing environment influenced the length of students' writing.

Quality of Writing in KO's Fifth-Sixth Grade

Improvements in the quality of the students' writing over the year are very similar to the changes in length. There was not a gradual increase in the quality of the students's writing as assessed by our modified holistic scoring procedure (Table 17).

%

Pet Desc.	Sep (pretest)	Jun (posttest)
Mean:	X=2.25 (n=21)	X=2.11 (n=21)
SD:	(.84)	(.69)

Event Desc.	Sep (pretest)	Jun (posttest)
Mean:	X=1.71 (n=21)	X=1.93 (n=22)
SD	(1.29)	(.98)

Classroom essays	Sep-Dec		Jan-Mar		Apr-Jun	
Mean:	X=2.25	n=50	X=2.14	n=73	X=2.33	n=30
SD	(.72)		(.61)		(.69)	

Newspaper articles	Nov	Dec	Feb
Mean:	X=3.6	X=3.8	X=3.6
SD	(21)	(14)	(19)
	n=3	n=5	n=5

Table 17: The mean holistic scores (0-4 point scale) for three types of writing assignments in KO's fifth-sixth grade.

Quality of Writing Tests. The description of the pet pre- and posttest essays were similar in both length and quality reflecting little change over the school year.

While the length of the description of an event decreased by about half from pre- to posttest, there was a slight improvement in the quality of the writing (+.22 points, SD=1.18). However the rate of improvement was lower than that of BL's third and fourth graders (+.33 points, SD=1.16) and much lower than that of the students in BMS's (+.79 points, SD=1.26) and KW's (+1.02 points, SD=1.07) class.

Quality of Classroom Writing Assignments. The slight variation in both the length and quality of the students' work over the year validates the low rate of change from the pre to the posttest for the students in KO's class. The pattern of change in the quality of the essays was the inverse of that for the length of essays. During the middle three months of school, students essays were longer, but this increase was accompanied by a drop in the quality of students's writing. From mid-year to the final three months, there was a slight decrease in the length and an increase in the quality. The overall pattern was a very slight increase in both length and quality. The rate of improvement however, was much lower than it is for any of the other classrooms.

Quality of Newspaper Articles. The quality of the newspaper articles in each of the editions of the newspaper was consistently high (3.6 - 3.8). But there were very few newspaper articles (3-5 in each edition) that were written in the paragraph format needed to compute a quality score.

While the newspaper project in this classroom was very similar in many ways to the one that occurred in BMS's and KW's classrooms, there were some important differences. KO did not have the resources provided by interactive writing tools, word processors, printers and news networks. The result was that more time was required for assigning articles, providing the necessary guidance in writing and editing the articles, and blocking and typing them prior to layout. Many of the students used interview forms or survey reports without summarizing the information in their own words. The few students who wrote articles in paragraph format were strong writers and the quality of their work was consistently high across the three editions. While the computer is not the crucial for a classroom newspaper project, a computer and printer can help create a learning environment which devotes more time to composing, editing and evaluating writing and less time to blocking, typing and layout.

Summary of Quality of Students´ Essays. The rate of improvement in the quality of students writing across all measures is not as high as in the other three classrooms discussed. On the description of a pet task there was no improvement. The description of an event posttest and the writing assignments in the last three month each indicate a slight (.19 and .22 points) increase from the beginning of the year. The gain over the year is not consistent; scores dropped midyear. A newspaper project without the help of computer tools was effective in helping students learn many important things about journalism, but did not provide the same focus on writing skills.

Standardized Tests of Language and Reading Skills

The California Test of Basic Skills was administered in May in KL´s school district so we were able to use these to examined the students´ progress in this classroom. Table 18 shows the grade-level equivalents for the subskills measures in the language portion of the CTBS for KO´s students.

LANGUAGE	OCT	MAY	READING	OCT	MAY
Spelling			Vocabulary		
Grade level eq.	4.1	5.1	Grade level eq.	4.1	4.6
SD	(1.1)	(1.5)	SD	(1.4)	(1.8)
Mechanics			Comprehension		
Grade level eq.	3.3	4.1	Grade level eq.	4.3	4.8
SD	(1.3)	(1.8)	SD	(2.0)	(2.3)
Expression					
Grade level eq.	4.1	4.6			
SD	(1.5)	(1.8)			
TOTAL			TOTAL		
Grade level eq.	3.7	4.5	Grade level eq.	4.2	4.7
SD	(1.3)	(1.6)	SD	(1.6)	(2.0)

Table 18: The results of the California Test of Basic Skills (CTBS) standardized testing for KO's fifth (n=14) and sixth (n=11) grade classroom expressed in grade level equivalents, at the beginning (Oct) and end of the year (May).

If all students were functioning at grade level, the average grade level for the class would be 5.5 in October and it would be 6.3 in May. As can be seen from the scores in Table 198the class scored one grade level below average in October in all language and reading subskills. At the end of the year the students remained below grade level.

A comparison of the reading and writing subtests suggests that the writing program in this classroom was effective in improving students' language. While the students show a gain of .5 for the reading skills, they show the expected gain of .8 for the language skills. The students show the highest gain in spelling, an area in which KO had placed a special emphasis.

The other classrooms in this study did relatively better on all measures of writing used in this study. However, the students in this classroom did achieve one grade level in language arts which is higher than is expected for students who began the year so far below grade level. This suggests that the writing program used in this classroom without the use of the computer writing tools was an effective way to teach students language skills. The evidence from the other classrooms suggests that the integration of the computer writing tools with the approach to writing used in this classroom would lead to a very effective writing program.

Conclusion

The students in KD's class do not show the same degree of improvement in their skills as did the the students in the other classrooms discussed. Their writing pre- and posttests do not show any gain in length or quality. The students showed the greatest improvement in both the length and quality of essays during the middle of the year, while scores fell off towards the end of the year. The production of newspapers without the aid of computer writing tools resulted in more time required for making writing assignments, guiding writers and the blocking, typing and layout of the articles. This left little time for the evaluation and revision of writing that was central in the newspaper writing experiences in the other classrooms.

While the performance of these students on writing tasks was not impressive when compared to the students in the other classrooms, the results of standardized tests (CTBS) suggest that these students did show the amount of gain that is expected for this time period.

Features of Functional Writing Environments

I have described the development of writing skills in four classrooms over a period of one year. I will now briefly compare the features of each of the classrooms and summarize student gains. From this comparison of the case studies we can make inferences about which features seem to contribute to the success of functional learning environments.

Functional Writing without Computer Tools

KO is an experienced teacher working at a familiar grade level without a computer or any computer writing tools. Teaching writing is clearly one of her strengths; her instructional strategies are very similar to those of the other teachers in this study. An indication of her dedication to language arts instruction is the school newspaper project that she organized and implemented.

Her classroom consisted of a relatively homogeneous group of low achieving students. Their group scores on standardized testing were about a year below grade level in all academic areas. Their educational history suggests that every year they will fall slightly further behind their grade level. While this expected pattern occurred in reading, the students' scores in the language area indicated a normal year's gain.

The students in KO's class did not show the same degree of improvement in their skills as did the students in the other classrooms discussed. Their writing pre- and posttests did not show any gain in length or quality. The students classroom assignments indicated the greatest improvement in both the length and quality during the middle of the year with scores falling off towards the end of the year. The production of newspapers without the aid of computer writing tools resulted in more time required for making writing assignments, guiding writers and the blocking, typing and layout of the articles. This left little time for the evaluation and revision of writing that was central in the newspaper writing experiences in the other classrooms.

In this case study, a skilled teacher who taught writing as a process from pre-writing to publication was able to help low achieving students improve their writing skills. Even though gains were evident on standardized testing the students essays over the year did not show the degree of improvement that was evident in all the classrooms using computer tools.

Computer Tools: Necessary but not Sufficient

BL faced a number of new experiences besides participation in this project. She was teaching at a new grade level, developing a bilingual program and learning a new method for language arts instruction. Like KW, her knowledge of computers and the computer writing tools was minimal. But unlike KW, she could not count on her students to help her learn. While any one of these factors alone could make her adjustment to this teaching situation difficult, she was also faced with difficulties in using the available software with her students. Many of the students had difficulty reading the writing instructions on the screen. It was also important to have the same computer task available in Spanish and English.

In BMS's and KW's classrooms the computer writing tools were successfully integrated into the curriculum at the beginning of the year and and the improvement in the quality and length of students' writing over the year was consistent. In BL's classroom, the students' inability to read the information on the screen made it necessary to make adjustments to the software and to the way it was used with students. The more successful introduction of computer activities created by BL towards the end of the school year were accompanied by a higher rate of increase in the quality and length of students' writing.

Despite these constraints, her students showed a substantial rate of improvement. The increase in the quality and length of student essays in this classroom are impressive. Given the difficulties that these students had in reading and therefore in the use of the software, it would not have been surprising to see little or no growth in the length of their writing. The fact that these gains begin to show up towards the end of the year, at the same time as the students were using the materials created by BL suggests that the successful integration of the computer with the writing curriculum may have had an influence.

Because of the skill level of her students, and the additional needs of bilingual students, BL took an active role in creating new activities to integrate the computer with her teaching objectives. BL's mastery over the system enabled her to create new computer tools for her students and a system that was flexible enough to allow for re-structuring made it possible to create a functional environment for these younger bilingual students.

An important dimension that this case study adds to our knowledge of writing with computers is the critical role of teacher's knowledge and the flexibility of the computer writing system. Computers and computer tools by themselves will not make students better writers. But computer tools used by experienced educators can create effective learning environments.

Computer Tools and Teaching Knowledge

KW, a teacher with a great deal of experience in teaching language arts, was teaching at familiar grade level, although this was her first experience with "gifted" students. Prior to this study she had minimal experience with computers. While she seen some demonstrations of the software, she began the year with much less computer knowledge and experience than some of her students. She relied heavily on students who learned quickly to help her and other students find solutions to problems that arose.

While at times struggling to master the computer and the writing tools, KW had little difficulty in extending her teaching strategies to include the computer as one of many work stations in her classroom. The students were quickly able to use the computer tools to extend their writing. The students in this class showed a pattern of increase in writing skills well beyond their grade level. However it is difficult to assess the degree of influence of the computer writing environment in this classroom for two reasons: (1) The students in this class were expected to make more than a year's progress; (2) judging their rate of improvement was difficult because of a ceiling effect in most of the measures. This effect was evident in project testing, evaluation of students' writing and in standardized testing by the school district. Even with the ceiling effect, the students in this classroom showed gains in writing that were similar to those of the students in BMS's classroom.

Comparing the students' writing across the year in different situations provides important information in understanding the features that contribute to a functional writing environment. The students' interest in editing each others work and the increase in the quality of writing doing cooperatively at the computer highlight peer review and collaborative writing as important dimensions of the learning environment described.

Computer Tools, Teacher Knowledge, and Computer Expertise

BMS had prior experience teaching fourth grade students and had both training and experience in teaching writing as a process. Her classroom was organized in learning centers and in the year before this study, she had experimented with computer writing tools to help students learn how to write expository texts (Miller-Souviney 1985). She served as a valuable resource in developing strategies for integrating the computer into the writing curriculum in all the classrooms. As in many classrooms, the students in this class represented a heterogeneous mix of skill levels with the class average at grade level.

The integration of the computer into the writing curriculum went very smoothly. The students in this class were able to master the use of a new form of technology for writing and do so while improving their writing and reading skills well beyond their grade level expectation. The use of student response groups for editing each others writing seemed to play an important role in the development of writing skills.

The evidence from this classroom indicates that a skilled language arts teacher with some prior computer experience can use the computer to create functional learning environments for students that are very effective in teaching language arts skills. The standardized test scores provide strong evidence that the students in BMS's classroom made significant gains in the quality of their writing over the year. The gain, on the average, of 3 grade levels in language mechanics and 2 grade levels in language expression are very clear. These findings were particularly noteworthy as gains in writing often do not show up in standardized testing. We know from past research that editing in context is more effective than completing grammar exercises to increase students' skill in writing. This classroom provides the unusual situation in which traditional grammar exercises were replaced by having students serve as editors of each others work. It may be that editing the work of others is even more effective than feedback on one's own writing.

I conclude by returning to the question that I asked at the beginning of this chapter: Does a computer improve students' writing? While it is difficult to say how much of the improvement, if any, can be attributed to the computer alone, the results of our research suggest that the functional writing environments that we created using computers effected the length and quality of students' writing.

CHAPTER 7:

COMPUTER ACTIVITIES IN A BILINGUAL SETTING

Luis C. Moll and Ann-Marie Newcombe

Introduction

The purpose of these introductory remarks is to specify the research approach used to study the introduction of a computer into a bilingual classroom. In particular, we want to make our assumptions explicit, discuss how our approach is related to our previous research in bilingual classrooms, and preview key issues. We will then describe in detail the bilingual classroom and present examples of the introduction, use and development of the computer and its relation to teaching practices.

The most obvious characteristic of BL´s students concerns language background; of the 30 students in the class, 10 were limited English proficient students (LEP) receiving bilingual instruction. Besides the bilingual character of the classroom, there were other important factors for understanding the impact of a computer in the classroom. Most notably, all of the children, regardless of language background, were classified as poor readers. More than the other classrooms included in the study, this class revealed the special issues confronting poor readers and their teachers when computers are introduced into a classroom. As third graders, these children were also the youngest students in our sample. Thus, not only were many of the children LEP, but they were poor readers and young, a combination of factors important to consider in analyzing the results of this study.

Furthermore, BL was one of two teachers who started the project as a computer novice. Thus, this classroom represented the type of classroom that the introduction of the technology is supposed to assist, one that contains "hard to teach" children who are taught by a teacher with limited computer knowledge.

The characteristics of this class allowed us to address three important issues regarding the use of computers in classrooms: (1) What does a computer-novice teacher go through when trying to use a computer in the classroom? (2) What problems do poor readers encounter in using computers? (3) How can computers be used with limited English-speaking children?

We tried to implement the same computer activities across classrooms in this project, in order to examine how the activities changed or were modified depending on the specific teaching-learning circumstances found in each classroom setting. In a real sense, therefore, each classroom formed a point of comparison for the others. The bilingual classroom experience reported in this chapter should be viewed in the light of the overall set of comparisons.

Assumptions Underlying Our Approach With Young LEP Students

Previous chapters describe our general approach to the use of computers in classrooms. This approach emphasizes (1) using computers as tools to accomplish well specified educational goals, (2) embedding computer activities in functional educational environments and (3) providing varying degrees of social support for novices, both teachers and students, in using the machines. We assert that there is no single prescription for effective computer use in classrooms. Furthermore, the search for a single program is not desirable. Instead, we propose general principles for the use of this new technology. The specific application of these general principles will differ depending on instructional circumstances. Consequently, there is no single bilingual approach to the use of computers; each program needs to be developed in the context of a given instructional setting and its goals.

In addition to our general approach, a set of specific assumptions underlie our work with LEP students, which influenced how we worked with the teacher as she used a computer in her classroom.

Emphasize Academic Development. In previous work (Moll and Diaz, 1984) we have documented the common practice of reducing the intellectual demands of the curriculum to match the children's limited English proficiency. This practice acts on the assumption that LEP children have no skills or are unable to profit from instruction until they became proficient in English. A similar situation has developed in the use of computers in education: affluent students are exposed to programming and problem-solving; poor students, especially language minority students, are relegated to drill and practice (CSOS, 1983; Boruta et al, 1983).

Our approach seeks to overcome this stratification by implementing similar goals and activites regardless of English language proficiency. Therefore, finding ways to organize the social environment to ensure the children's participation in advanced computer activites was an overreaching goal of this project. We wanted children in all project classrooms to engage in comparable computer activities. Consequently, it was not a matter of using computers, for example, for writing and for bilingual education, or problem solving and for bilingual education, but a matter of using computers to organize academic activities to achieve the same high academic goals in different teaching-learning environments, including a bilingual setting. Therefore we address the use of the computer to teach oral language development in English only in so far as that topic relates to the attainment of broader academic goals. We also address the development of bilingual software as a means of facilitating participation in advanced computer activities, not as an isolated technical issue.

Capitalize on the Children's Skills. We also wanted to develop computer activities that made biligual skills an asset, or at the very least, took advantage of the children's oral langugage and literacy skills in Spanish. We viewed the introduction of the computer as a broader pedagogical issue regarding effective bilingual instruction, not as an isolated technical issue regarding the teaching of skills to use a computer or teaching students to become computer "literate."

Capitalize on the Teacher's Skills. We realize that an attraction of drill and practice is that it can be done without much teacher involvement. Our approach requires more active and direct involvement from teachers. This need for involvement posed a dilemma. Given that the bilingual teacher was a computer novice, we needed to organize activities that helped the teacher to use the computer in sophisticated ways while she developed expertise in the use of the machine. In order to counter the tendency to reduce the level of computer activities to match the children's low academic level and the teacher's lack of computer knowledge, we tried to design a system of support for the teacher's use of the computer in the classroom.

Implementing Computer Activities

Computers are the rage in education. But nothing seems to intimidate teachers more than the idea of using the machines in their classrooms when they are not facile in their use. It is only a slight exaggeration to claim that this was BL's situation at the beginning of the project. Much to her credit she persevered, even after some initial discouragement, to implement computer activities systematically and successfuly, gaining competence and confidence as the year progressed. In the following section we describe the introduction of a computer into her class.

The First Phase: Getting Started

In a real sense, the first three months of the school year were "on the job training" for the teacher. Her knowledge about how to use computers was minimal and she was not sure just what to expect from either the machines or the researchers in her classroom. But as we will discuss later, the uncertainty of this first phase allowed her to experiment with different activities and approaches, and to discover how much she could do as well as the constraints that she faced.

There are several issues related to "getting started," most were quite pragmatic. In particular, as she assumed responsibility for teaching with a computer, she wanted to make sure that she did not neglect her other teaching duties, which were considerable, and that the LEP children did not fall behind the rest of the class.

Organizing Computer Use in the Classroom. The first concern was finding a way to structure computer use in her classroom. This concern was reflected in the care with which the computer routine was organized (see Chapter 2). In brief, a computer corner was established and a schedule posted on an accompanying chart specifying which children were supposed to be working on the computer, on what day, and for how long. Software set aside specifically for children using the computer during math, reading or homeroom time. Monday mornings were established as the time to provide instructions about new assignments or to introduce new software. Assignments were monitored by the teacher in order to assess the children's progress or problems. Discussions were held with colleagues in the project on how to improve the presentation of materials.

This routine worked well. The children learned it rapidly and adhered to the schedule readily and consistenly. By the second week most of the children were following the "computer schedule" without teacher supervision.

One consistent and important finding is that the computer activities retained their motivational qualities throughout the year. Rarely did a child resist working on the machine. During those times that the schedule had to be modified temporarily, abbreviated school days, for example, the teacher needed to reassure the children that she would rearrange the schedule so that everyone had equal access. That computers initially excite and motivate children may seem evident, particularly given the popularity of computer arcades, but considering the repetitiveness of most curricula and the negative (dull) conditions usually associated with classroom work, it is impressive that the computer activities were able to elicit enthusiastic participation from the students all year, regardless of the changing nature of the software. It may well be the computers' arcade and game history that make them such a powerful "lure" in the classroom, even with children that have little or no previous experience. During the first two to three weeks, small groups left their desks to "hang out" around the computer watching others work, sometimes making comments to the users or among themselves. Such behavior is reminiscent of what youngsters do at computer arcades, especially when they want to learn a new game (or when they are broke!).

The computer-using routine in this classroom was also characterized by flexibility and diversity. Instead of providing only one way of introducing the students to computers (e.g., programming or keyboard practice), the teacher made available "multiple entry points" to computer use (Levin & Souviney, 1983; LCHC, 1982). About 10 software programs were used during the initial six weeks (see Chapter 2). In some cases software was changed or its use postponed because it proved too difficult for the children. However, in general, children who were unable or unwilling to engage in a particular task were offered alternatives. That is, students were not excluded or relegated to lower-level work when they had difficulties with a particular program. Instead the software was replaced or modified, or social assistance was increased. A rapid means to create multiple and varied environments for learning is one of the advantages of an interactive computer system that provides dynamic support to teachers and students alike.

During the initial weeks the teacher also tried several ways of relating the computer activities to other curricular tasks. For example, the children were asked to write brief essays that were then transferred to the computer. In such cases, the paper-pencil writing activity functioned as preparation for writing with the machine, and the machine became a context in which students' writing with pencil was expanded or revised. Another example comes from an English lesson with the LEP students in which the teacher asked the children to make sentences using computer terms.

Clearly, the introduction of the computer into the classroom created additional work for the teacher. Not only was more preparation required, but she had to pack more activities into an already crowded curriculum and deal with the extra interruptions from children seeking help. Most of the children's problems during the first phase involved computer or program operations —mistakes or problems in making the machine or program work. Throughout the initial phase the children relied on the teacher as the primary source of support and information. This reliance is not surprising, given that the class was teacher-centered to a great extent. This state of affairs underlines two important considerations in computer use: 1) computers do not stand alone; 2) regardless of the presence of the machine, the teacher must still teach. Teachers must organize activities involving the computer just as they must organize activities for reading, math or science. They must schedule work routines at the computer just as they must plan reading group rotations or excursions to the library. There is no doubt that the act of introducing a computer into a classroom is a lot of work. Much of this work is very frustrating as something always seems to go wrong: a program does not run, the screen goes blank, the kids do not understand the directions, they forget to save what they have written on disks, etc.

As research into classroom computer use continues, it will be important to determine whether the introduction of a computer causes special and particular problems, or whether the problems are similar to those associated with the introduction of any new curricular activity. Initially, all these problems disrupt the flow of the classroom routine. Consider some common examples we observed.

> "John asks BL if it is time to go on the computer. He is scheduled with Aaron (who is absent) at this time. BL chooses Christian to be John's partner. They read outloud the instructions on the monitor. Christian is a slow reader. John is a better reader. They seem confused. Christian says, 'I gotta go get Ms. L.' He raises his hand. BL acknowledges and says she'll be there in a moment. Christian is still raising his hand. He stands up. BL comes over. She starts them over by pushing CTRL-Reset and tells them to type in PR#6 and leaves. The boys type in PR#6 and get a syntax error. Christian again wants to get BL. She is busy and doesn't see his raised hand. John is quiet until he says 'Press CTRL-Reset'; Christian: 'How do you know?'; John: 'I know'; Christian: 'No you don't. Ask Ms. L.; John: 'You ask her.' Christian stands again and BL comes over, retypes PR#6 and leaves again."

Most of the children, as in the example, go get the teacher as soon as they encounter difficulties. Practically all children we observed during the first phase sought help from BL every time they used the computer (see Chapter 6 for details).

To avoid being interrupted so often, the teacher posted instructions near the computer or wrote them on the section of the blackboard nearest the machine. We found only a few examples of written instructions being used effectively by the students to help themselves proceed with the computer activity. The issue of reliance on social instead of print resources is a general pattern in all classrooms. The pattern may have been exacerbated by the children's low reading levels, an issue that we examine next.

Bilingual Support in Interacting with Software. Perhaps the most pressing problem in this particular classroom was the children's low level of reading. Software programs, even the simpler ones, require children to read, either to follow intructions or as part of the activity. We observed many of the children unwilling to read the text on the screen. A well documented consequence of being a poor reader is that one avoids text (cf. Hood, Cole and McDermott, 1980; Kozol, 1980; Rueda and Mehan, 1985).

During the "start up" phase, most of the software programs were in English only. Thus the LEP children found themselves at an additional disadvantage. As mentioned earlier, providing all of the children with a comparable curriculum regardless of their English language fluency was one of BL's priorities. The teacher provided instructions in Spanish and translated key terms to facilitate the LEP children's participation in the same activities as the rest of the class. Below are three examples of how this help was given:

> The game is called Shark, the children select the coordinates to fire a harpoon at a Shark; if the harpoon misses the computer provides feedback to help the children adjust the aim. Pat and Monica, two LEP girls are playing the game with the help of the teacher. The teacher first goes through the "booting up" motions, asking the girls questions in Spanish to ascertain whether they understand the procedures (Que es lo primero que tienen que hacer?; Como vamos a saber si la pantalla esta prendida?). The girls either answer or do the action required.
>
> The program is booted and the first question appears on the screen (What is the name of your school?). BL translates the question into Spanish and tells the girls to each type on letter at a time. The girls type in the name of the school and BL asks them what they should do next after they finish. Monica points to the shift key and BL says no. Monica then points to the Return key and BL says yes. As the game continues BL translates the instructions into Spanish to assist the children.
>
> With the teacher's help Monica finally gets a hit. Her partner, Patty,

takes her turn and she gets a hit on two tries. As the girls seem to get the idea, BL continues to provide Spanish instructions, but little by little she introduces Engish. The teacher's goal in providing support was to help the girls participate in and understand the game, so that they could play without her constant supervision. Because the teacher could not possibly take the time to help all of the LEP children every time they used the computer, the observers, who were all bilingual, agreed to provide similar help as needed in engaging the children in the task. In the next example the observer assists the children with Speed Read, a game all of the children found difficult because of the rapidity with which words were displayed on the screen.

AM (the observer) helps the children get started by providing a Spanish translation of English instructions, similar to the example above. As she reported in her field notes:

> "Again the words flash on too fast, even at slow speed. The words that flash are in Spanish (they have been traslated but the instructions remained in English), but Alberto did not realize this. I think this is because all of the instructions were in English and I translated, and then when the words flashed on it was so quick that he didn't notice it had switched to Spanish. In fact, at first he didn't believe me when I told him they were in Spanish. Because the words were flashing fast, the boys would look at me to see what to do. What I did was say the word aloud and then see if they could type it in within the amount of time given. About 75 percentof the time they were able to type the word in within the amount of time given, if I told them the word. This does not mean they always spelled itcorrectly. The other 25 percent of the time, time ran out and the computer would count it as wrong.The boys wanted to try again so we went through it once more. It was the same list of words. This time I had them watch the screen closely and see if they could do it on their own, but it wasn't very successful. They would be able to see and be able to see and read the first few letters and then the word would flash off."

In this instance the Spanish translation helped the children get started, but the game proved too difficult. However, notice that the children were able to write the words most of the time if they were said aloud by the observer, showing that the difficulty was in decoding rapidly, a common problem with young readers. In the following example note that the English monolinguals have the same problem.

> "Christian and John are doing Speed Read. After some help from AM in getting the program started, John reads the instructions on the screen. Words then flash on the screen very fast and he is supposed to spell it but only has a certain time to do it in. The boys take turns, one word at a time, and try to spell it... The boys are not getting any right. (They decide to try another program.) ...there is a lot of text (on the screen)...John reads one screen full. I read the other two screens of text...Christian is impatient and wants quit and skip the instructions and go on to the next screen before we were finished."

The comparison shows that it is not solely the LEP children's lack of oral language skills that makes working with the computer difficult; the English monolingual speakers had similar problems. What both groups have in common is that they are poor readers and interacting with computers independently requires good reading skills. One way to alleviate this problem would be to not allow children to do any computer work until they became proficient readers. But this practice reduces access to the machines and denies potential benefits to the very children one hopes computers will help. A second way would be to select software that minimized the requirement to read. But that alternative eliminates the most interesting and potentially useful software.

The teacher's alternative was to compensate for the children's lack of reading skills in ways that allowed them to interact with computer programs. The teacher provided verbal and reading help to the children as they worked on the computer. This alternative incorporated the principle of dynamic support which has been discussed throughout this report. In this particular instance, the assumption was made that with this help and the progress in reading expected from regular reading lessons, the children would be able to hold their own in a few weeks. Indeed, during the final three weeks of the first phase we started noticing that some of the children were beginning to proceed with less help, as the following examples illustrate:

> "Adrian and Alberto sit down and ask me what to do. I speak to them basically in English and switch to Spanish to clarify an instruction. ...The text was coming out (on the screen) in English, not in Spanish. At first, when they complained about being in English, I told them they could still do it, since usually the introduction to these programs are not translated... We tried ´Starwars´ (from Storyland) ...but the prompt lines were in English and they were discouraged by that. I forced them to read it and then I would translate.
>
> They push the last choice and must continue the story themselves. They don´t understand what they are supposed to do. I explain in Spanish that they are to write on the computer and finish the story themselves. I read to them what they´ve written so far and tell them to continue... They proceed by taking turns in selecting the sentences to make the paragraph.

When it was time to stop they are unsure how to proceed, so AM had them read the prompt line. The prompt lines were in English which intially made them complain and not try, but AM had them read the prompt and translated what they did not understand. In this manner, they got through ending, writing and saving the text. The children were not interested in reading the first paragraph they did, which was based on their selections, but wanted to read the second paragraph which they composed on line. The next week they manage to spend more time composing.

Adrian asked AM what he and Alberto are supposed to do. She points out the disk and Adrian complains that it is in English and that they want it in Spanish. AM tells them that the disk is also in Spanish, so they put it in and the program starts. The intructions are in English so the children turn to AM to find out what to do next. She tells them to read it and as they read she elaborates on each point. Adrian chooses to write about news and they start to write. Alberto says something referring to Adrian getting into trouble. Adrian tells him to go ahead and write about that, and they both look at AM for confirmation that it is okay. The boys start discussing particular words and what to write and for the next 10 minutes they help each other write. AM tells them that their time is up, but Adrian does not want to stop. With AM prompting they get through the procedures for leaving the program, naming the text, switching disks, saving the text, and turning off the computer.

Thus, we have indications that these children, among others, began to function independently, at least to enter text. However, they still needed help leaving the program and saving what they wrote.

Summary. The first three months of the school year involved implementing a schedule for computer use in which everyone in the class had equal access to the machine and in which all of the children, regardless of English language fluency, would engage in comparable tasks. What is most clear from our observations is that introducing a computer into a classroom requires extra effort from the teacher, especially if the children are poor readers. It is simply not the case that all the teacher needs is good software and a sequence of activites and the machine does the rest. The use of the computer is always mediated by classroom social processes, most of which are controlled by the teacher's previous procedures for organizing instruction and constraints imposed on the classroom from outside.

Instead of organizing a fixed activity schedule for the children using a predetermined sequence of tasks, the teacher presented the students with a variety of software programs and tried to relate the computer activities to other aspects of the curriculum. Progress was slow. It took the children several attempts to learn computer operations and program procedures. Although mastering operations and procedures was particularly difficult for the LEP children, the teacher did not relegate them to less demanding computer activities that would match their low level of oral and reading proficiency. Instead, the teacher sought to provide the social resources necessary to permit these children to engage in the tasks the rest of the class was doing. This strategy proved to be laborious, but effective. By the end of December, there were indications that the children, including the LEP students, were overcoming difficulties with procedural matters and participating in computer activities profitably.

The Second Phase: Developing Expertise

During the Christmas break, we evaluated our experiences from our first three months of observations. One thing was clear: we did not have any spectacular results of children performing wonders with computers. However, scrutiny of our notes and videotapes revealed changes in the children's computer work, changes which served to establish new conditions for computer use during the remainder of the year. After discussion with the researchers and the other teachers on the project, the teacher decided to have the children concentrate on a single software program for a prolonged period of time. In particular the teacher was interested in implementing the Computer Chronicles (CC) with the entire class. We hoped that by constraining the number of computer activites we would help ease the burden on the teacher, allow her to learn new software programs and provide the children more time on task with the same software. We also obtained a printer to use in the class, an addition that proved to be most useful because it provided the children with tangible results of their work on the computer.

The teacher was also interested in developing her own software, tailored to the LEP children, to supplement their work on Computer Chronicles. During the second phase she learned how to program interactive texts and developed Storyland stories in Spanish. This innovation proved successful in providing the LEP students with yet another entry point into computer activities that had an English-language equivalent they would eventually use. It also provided the teacher with more control over the functioning of the machine. In a sense it allowed her to understand and participate in the computer activities at a different level. Instead of being only a consumer of what others gave her, she became a producer of activities. Our initial observations in January gave us the impression that the children (see Chapter 5 for more details) were indeed much more familiar with the procedures and spending more time on the content of the programs. This was certainly true of some of the children, although we also observed many problems. The following is a typical example of the children working competently with a minimum of help:

> "BL called Nicola and Julie to the computer. She asked them to work with 'The Adventures of Horus,' a user controlled program in which the students can either select from available sentence fragments to complete a sentence or write their own story. The girls look for the disk and finally find it.
>
> They turn on the CPU. Nicola types in first 'Nicola and' Julie then types in her name 'Julie,' Nicola hits Return. N: 'You do this next one' J: 'Ok, what do we do?'
>
> Horus starts. The first turn is to type in the name of an animal. Nicola types a name in despite it being "the next one" which Julie was supposed to do. Julie does not seem to mind. Nicola is typing in all the commands... The girls discuss what color to enter on the next turn. The third choice is ok with both of them. Nicola goes to type it in and then says "No, you do it" to Julie. J:"ok" and types in the color. Nicola hits Ctrl-C. Nicola is seated at the 'keyboard seat.' Next turn, the girls must enter a wish—Horus' wish. J: "I wish I could have a dog." N: "um...or a cat" J: "Yeah,

> I wish I could have a cat." Julie starts typing in the sentence. The girls seem to be taking turns, one word at a time, for the first three words. Then, Nicola finds a mistake on the third word, she erases "the whole word" and retypes it. She finishes the sentence.
>
> Nicola had gotten up and now comes back with two reading books. She uses the title of the top book, Superfudge, to use and enter as a type of book...
>
> N: "You do this. I've been doing most of this". When Julie moves over to type, Nicola moves her hands away and takes over.
>
> The girls needed help with "cooking utensil." They didn't know what that was exactly... They need help with an adjective for the story... Nicola and Julie finish the story on the computer and are now reading their text on the screen. They saved it on their own."

Although the girls were able to use the program with little difficulty, they obtained strategic help from three different sources available in their immediate environment. One was the software program itself, which provided them with the option of selecting pre-written sentences or the opportunity to compose their own. This closing feature provided a clear structure for the students to place their sentences that served to guide their writing, and a goal related to that structure. A second source of help was each other. They collaborated, for example, in typing, making selections, and composing. A third source of help was the observer. They turned to the observer for assistance, clarifying procedures, defining words, and so on. As the children's performance improved they sought help from sources other than the teacher. That is, the source of support shifted from reliance on the teacher to other places in the environment.

This shift in ways of working with the computer was also evident with the LEP students. In the following example the children were working on a Spanish version of Storyland that BL developed specifically for her class.

> "As they start Patty reads the text outloud while Monica whispers along with her. They choose 'creando oraciones simples' (creating simple sentences).

> Monica tells Patty which number to select, and then Patty types it in and hits return. This division of labor was designated by Patty and agreed by Monica. Monica now has taken over reading what is on the screen outloud. They read through most of the selections before deciding. Sometimes Patty would not agree with Monica's choice, so she would suggest some other one and wait for Monica to agree...BL announces "5 more minutes."
>
> Patty is now reading and telling Monica what # to select, and Monica types it in and hits return... The girls are now on their fourth sentence. Patty calls me to see because they wrote a funny sentence..."el lobo escapo dentro de la television y tiro al maestro a la calle." They do one more.
>
> Nicola & Julie come over, it is their turn now. Patty & Monica turn off the monitor and take out the disk."

As in the previous example, the students relied on each other to complete the task, shifting the division of labor as needed. However, in our observations of the same children a week later, knowing computer operations did not guarantee that the children would interact with the content usefully.

> "The girls are typing in their names. Monica tells Patty to write her last name too (Patty is writing her name in first) and then Patty writes her name on the blackboard to check her spelling on the computer. Monica types in her whole name too.
>
> The girls get to the first set of selections in Storyland. Patty is on the keyboard. She turns to Monica 'poncho peludo, number three,' M: 'No peludo' She looks at the screen and Patty just pushes the number. Patty just wants to push 'lo que sea.' (whatever). Patty is doing the typing and the hitting of Return. She reads out loud a little, then seems to get tired or bored because she verbalizes, in English, the same selection for three turns after that; she just picks a number/selection without reading the choices. Monica, on the other hand, likes and seems to want to read the choices available but Patty is too fast and passes on to the next set.
>
> The girls start on a second paragraph. M: 'yo le poncho los numeros y tu el Return' (I hit the numbers and you Return), negotiating about turn taking. P: 'Tu punchas el Return y yo el que quiera" (I hit Return and I hit whatever I want.). Monica accepts this. The girls continuue. Patty still choosing numbers without reading the text. She begins to humm, quite loudly, Rudolph the Red Nosed Reindeer. The girls finish the paragraph. The computer is prompting them to answer Yes or No if they want to continue. They ask me to choose for them. I say No (because of time). They start

> the saving procedures. They switch disks when I tell them to. I read the prompt lines in English. They seem to understand. They want to see what they wrote and it is put up on the screen. They read it aloud together.
>
> The computer prompts asking if they want to print their text. I explain the printer and what "to print" is. We go through to get two copies."

The same inconsistent performance was also evident with the English monolingual children:

> "Mandy says to the me (the observer) that she (Mandy) does not know what they are supposed to do. I point to the blackboard where BL had written the assignment. She looks and gets a puzzled look. AM: ´What does it say?´ M:´Number one Computer Chronicles.´ AM: ´And after that?´ She reads the rest of the assignment but does not seem to understand yet what to do...
>
> (The observer explains what to do and the girls start the disk; they decide to write about a TV program.) Mandy reads aloud what is on the screen. R: ´Do you know one?´ M: ´Webster´...Ruth suggests to write that the program is good. M. ´Are we just going to say it´s funny?´ AM: ´You write as much as you want.´...Mandy turn back to the computer and screen. Ruth hits CTRL-C after that one sentence. Mandy complains taht they wanted to write more. I tell them to push CTRL-C when all done. M: ´We´ll have to start all over again!´
>
> The girls enter one sentence of their review. It is a little longer that the other one. (Ruth hits CTRL-C.) M: ´You did it again!´ R: ´I did not.´ Mandy hits CTRL-Reset and says ´we have to do it all again!´ after only one sentence."
>
> The two girls proceed in a similar way for the rest of their time, completing barely one sentence in their allotted time.

A few days later, just when it seems that these girls will never get anything done, they are much more coordinated and on task.

> "Ruth and Mandy start. They take turns writing out the date. They ask me what section they are to do. I point to the board where the assignment is written up. The girls arrive (on the computer) to where they enter their story. They are going to enter Ruth´s story. Ruth begins typing. Mandy corrects a mispelled word. M: ´This is my turn,´ and she types in a word. R: ´I do the next.´ They are dividing up the task word by word. After the first sentence , Mandy tries to hit CTRL-C; Ruth and I stop her. AM: ´When do you hit CTRL-C?´ M: ´When you are done.´ AM: ´When you are all done, otherwise the computer thinks you are all done, finished with your story.´ M: ´We have to make sure this makes sense.´...

> M: ´What is next?´ R: ´my friend...you write my." Mandy types it in and Ruth does the next word...M: ´We never start a sentence with and. Never!´ She backs the cursor and erases ´and.´... Ruth suggests, ´Me and her.´ Mandy responds that ´Me and her doesn´t make sense. Me and Danielle does.´ They decide that is what they will type."

The girls continue to discuss the content of what they are writing as they compose and check for mistakes. They also comment that they are writing much more now than the last time. Throughout this process the observer provides strategic help by making sure the girls don´t get bogged down on the lower order computer operations, such as when to push CTRL-C, that may distract them from the purpose of the activity which is writing a narrative.

A striking example of how much this "lower-order" help can ease constraints that may limit what the chidren can in fact produce is provided next:

> "Patty is on the computer. Her partner Monica is absent. BL asks me to be with Patty. I go and ask her if she knows what she is to do. She says no but then asks if she is to get her story (for CC); I tell her yes. She has written on both sides of the paper on her Perfect Friend. She boots up and we get to where she is to begin writing.
>
> She starts typing in the story, following word by word. She is real slow but seems to know where most of the letters are on the keyboard. I ask her if she wants me to type and she tells me what to put in. She agrees because ´it will go faster, verdad?´ She dictates to me until she finishes what is written on the paper.
>
> I ask her if she wants to say or write more. She says yes. I ask her what and type it as she tells me. I start telling her she has to watch closely and make sure that I don´t make any mistakes... She started beginning sentences with ´and´ so I ask her if a sentence can begin with ´and.´ She says yes; I explain that and is a continutation... I give her an example of how she can begin her next sentence without ´and.´ She continues dictating. I don´t write a period unless she tells me, though sometimes I will prompt her and ask her if it is time for a period or not."

Patty saves her text and they get three printouts of her story. Contrast what she wrote, for example, to what Gregg was able to do unassisted. Patty´s draft is over twice as long as Gregg´s or any of the other examples we accumulated. One consequence of eliciting this extended amount of text in a short period of time from a beginning writer is that it creates plenty of opportunities to teach other aspects of writing and grammar that may not become available when the amount of text produced is curtailed. Indeed, in the comments we cited above, the observer was able to teach writing as a result of providing the type of help (in this instance with typing) that removed constraints, even if temporarily, thus extending the writing. This extension, in turn, gives us a glimpse at what the student could really accomplish, providing a different view of the student's competence.

In sum, the children were able to do some text editing on-line and they collaborated more readily to complete a joint product successfully during the second-phase. These changes were as evident for the LEP as for the English-monolingual students, indicating that the teacher was being successful in helping both types of students perform similar tasks and at similar levels. Progress, however modest, was now becoming more evident. It continued into the last two months of the project, April and May, which we will now examine.

The Third Phase

For the last months of the project, the classroom computer activities required the children to compose text on the computer and to modify their drafts. What follows below are selected examples that trace the improvement of the children. These changes were not uniform; if anything they were characterized by uneveness. Children who seemed to be mastering the tasks gave the impression of not knowing what to do during the next session, and vice versa. The examples also show that children's writing must be understood in the context of the conditions that we create for them to learn.

Writing in this phase included letters and stories for the Computer Chronicles. The procedures followed in producing text varied considerably depending on the students. The first sample presented below is by two LEP girls, Francisca and Mercedes, using the Writer´s Assistant text editor. This was the first time they had used a text editor and felt rather uneasy about what they were doing. They were entering text they had written previously with paper and pencil. They decided to take turns with one dictating what was on the copy and the other entering text. Rather than the continuous turn-taking which characterized their and other students´ earlier collaborations (see Chapter 4 for details), they decided to exchange turns after a more prolonged period of time. This exchange was not without conflict and negotiations, as the following discussion illustrates.

> "Francisca starts dictating. Mercedes types. They have a paper and pencil copy. Francisca tells Mercedes, ´let me write it now,´ and she moves over into Mercedes´ chair to be in front of the keyboard. Both now share one seat... Francisca does not know how to spell ´Alberca´ (swimming pool); Mercedes begins to spell it out and corrects Francisca...She begins to erase the sentence and the previous one; I ask her what she is doing and she stops. Mercedes again dictates the sentence that F erased and then exclaims that it is her turn. The girls switch seats. After the first sentence, Francisca says, ´ya es mi turn. Ya te toco un period.´ (´It is my turn. You already wrote a period.´) ´Mercedes responds, ´yo se, pero a ti te toco dos veces.´ (I know, but you had two turns.´)
>
> I ask the girls if this is the first week they use (the systems editor). Mercedes says yes; she also tells me that (two other girls) erased it all the other day because they were goofing around. The girls again switch seats. F says, ´Estamos escribiendo mucho, verdad?´ (´We are writing a lot, right?´) M keeps telling F to hurry. Francisca dictates but is not really paying attention to the screen in order to correct spelling, etc. For example, M types ´plalla´ (beach) for ´playa.´ I noticed that F has it spelled correctly in her paper but she does not correct M. The girls finish entering text. Now what? they ask me. I point to the top of the screen and tell them what to do next. We save the text by me telling them what to do and by pointing to where on the screen (the directions) appear."

Several other children followed the procedure of typing in text they had produced previously with paper and pencil. In most cases, with the children on line, the observer provides help with the writing process. The next writing sample is by Holly. As she was getting ready to write, time ran out because her partner took so long in entering her own story. Consequently, Holly returned during her lunch hour to enter her story.

> "During lunch break, Holly came in and asked BL if she could do her story now. BL says it is ok... I ask Holly if she wants me to type. She says yes because it will go faster... As Holly dictates, I ask questions to clarify the sentences. For example, Holly dictates, '...and then he punched him.' 'Who punched who?' I asked. Holly then clarifies her sentence, 'Super Bunny punched the man down!' We get ten lines and her story is finished . I tell her how she can save. She follows instructions fairly well and gets me a printout."

Rodolfo and Noe received similar help from the observer in writing a letter to their mothers. The observer took over the typing duties, leaving the children with the responsibility of composing the text collaboratively and in interaction with her. While the children were dictating the letter, the observer provided selective prompts to guide and clarify their writing.

The final example provided is by Michelle working alone. The observer gave her some initial help with the procedures on how to enter text using the systems editor and the rest was done by the student. This time the observer did not provide assistance with composing and the student typed the text in herself. Notice the spacing between letter and the frequent periods. Also note that she uses the English 'miss' for the Spanish 'mis' (my). Mistakes and typos notwithstanding, this student composed on-line and wrote for communication. In the process she produced sufficient text for the teacher to teach writing.

One value of observing children over time is that we learn that development, of writing in this case, is not linear and neat, but discontinuous and messy. Through prolonged observations we are also able to gather evidence of change that is easily missed with single observations, especially when the children are "hard to teach." Equally important, in situ observations reveal what it is about the way instruction is organized to facilitate or constraine children's progress. The examples presented above between assisted and unassisted writing suggest that help with typing and help with the actual writing process facilitate sound writing. This is no surprise. However, a teacher rarely has an observer in his or her classroom who is willing to help the children with their writing. Some of this help can be built into the software program, but that help, we found out, was rarely sufficient, especially for beginners.

This finding suggests that the teacher must use regular writing lessons to provide practice with the process of writing and grammar, while writing with the computer could become the central communication activity for the class. In an important sense, regular lessons must help create the conditions for the use of the computer. The lessons must function in lieu of an adult supervising the writing process on line. How to organize classroom lessons to provide the children with the social, linguistic, and intellectual support to take optimal advantage of what computers can offer is the greatest challenge facing computer-novice teachers.

Conclusion

We would summarize BL's experiences introducing a computer into her classroom in these terms: It was laborious and at times exasperating. The children's progress was slow, unveven and often hard to detect. The computer did retain the students' interest all year. Most children were eager to work with the machine and seemed to learn the necessary computer operations and do some writing.

It is clear to us that the mere presence of this new technology in a classroom will not produce major changes in instruction. The equipment is embedded in an instructional system; it is the system and not the machine that is responsible for change or maintenance of the status quo. Computers are no solution to difficult instructional problems and do not replace teachers. Given the current state of software distribution, LEP students may only be exposed to drill and practice activities. In addition to providing differential access to important educational resources along ethnic lines, this practice will further discourage the development of basic educational skills.

It is equally clear to us, however, that computers afford teachers a medium, a novel way, an opportunity, an excuse, if you will, to question the status quo. What is it about the ways we organize instruction that even the introduction of these wonderful machines has no visibly important effect on classroom organization?

BL's classroom, the characteristics of which we have described in previous chapters, presented formidable constraints to the "effective" use of the machine. These constraints, most of them systemic, such as classroom scheduling, curricular goals, books, and particular groupings of children, established the boundaries for action. They, at the risk of sounding too colloquial, define the nature of the game and much of how it can be played. BL's first responsibility was to implement the curriculum in good faith. But she also had to think of how, without neglecting her teaching duties, to introduce the computer in ways that could help the children. Her situation is typical of most teachers. And under such circumstances the computer easily becomes an intruder whose potential benefits are outweighed by the inconveniences they create. The strategy of choice then becomes, not by design but by necessity, to accomodate the machine to the prevailing constraints. This decision, although pragmatic in the short-run, is absolutely fatal, especially for language minority students. It assumes, uncritically, that the status quo is the appropriate context for computer use. Invevitably, existing curricular practices become the "model" for computer use. Why should we expect that the same practices that have produced widespread academic failure will create propitious environments for computer use?

From our perspective, adapting computer use to prevailing educational practice (i.e., drill and practice for language minority students) has one immediate consequence: it reduces teaching with computers to computers teaching kids. The teacher then has no choice but to rely, indeed, trust the software. Little of what we have read, reviewed, or observed would suggest that such trust is well-placed. In fact, the consensus of the field seems to be that most educational software is less than helpful (Lesgold, 1983). Additionally, if certain children have problems with the software assigned, one of the teacher's few options is to select simpler software, reduce the level of difficulty of the assignment, or, as is commonly done with reading and math, break up the assignment into small, discrete steps that the children must master before proceeding. Another common option is to decide that certain children, for example, limited English-speaking students, are simply not ready for computer work, at least not at the level of other, more advanced (English fluent) students. As mentioned in the introduction to this chapter, computer work in schools, despite the newness of the innovation, is already characterized by such stratifying practices. This fact should not surprise us, it reflects broader, long-standing curricular practices which are the norm in most schools.

What can we offer besides warnings about reductionism and tracking? Fortunately, we do have many positive examples of computer use with a variety of children and situations. From our experience two key principles emerged and both highlight the importance of the social context of computer use. One is the need to subordinate computer work to a higher order goal. We were particularly successful when communication with other people was the goal of writing activities, that is, when the task being done had a real purpose that made sense to the students. Another is the coordination of resources around a common goal. We were impressed with the students' use of social support from a number of sources to accomplish their computer tasks; written support or help from a single source was rarely sufficient.

All classrooms are social environments purposely organized to achieve social and intellectual goals. As such, classrooms are not "natural environments," they are "artificial" or socially created entities. Our findings indicate that specific classroom practices mediate the way that computers are used. They help define the nature of computer activities.

This sounds obvious, but it is important, because it challenges the popular notion that computers are "general purpose" tools adaptable to a wide range of classroom conditions. This adaptation notion is problematic, for reasons we emphasized earlier. If classrooms are social creations, then they can be socially re-created or re-constituted in fundamentally new ways. Therein lies the importance of computers in classrooms, not necessarily in providing new technological solutions, but in making visible how much our social arrangements constraint children's thinking; in providing new reasons to question the instructional conditions under which we ask children to learn.

CHAPTER 8:

TEACHING PROBLEM SOLVING STRATEGIES

Marti tum Suden and Robert Rowe

We wish to thank Steve Black, Nick Maroules, and Randall Souviney for their comments on this chapter.

Computer programming is one of the most prevalent instructional uses of microcomputers in schools (Becker, 1983; Boruta et al, 1983). Programming is often emphasized because it is presumed to have a positive influence on higher order thinking (Papert, 1980) and because it contributes to "computer literacy" (Luehrman, 1980).Learning to program a computer is said to develop conceptually clear thinking because programming requires precise expression, planning, rigorous thinking, and the manipulation of explicit statements in the generation and testing of hypotheses. Therefore, as students learn to program, they presumably learn about problem solving processes. Once students learn to solve computer programming problems, they presumably will be able to transfer their problem solving knowledge to other domains.

The belief that learning to program a computer improves problem solving is the most recent instantiation of the belief that rigorous disciplines such as logic, geometry or Latin "exercise the mind" and enhance higher order thinking (Pea and Kurland, 1984). It was this line of thinking that led to the development of the LOGO programming language as a microworld or learning environment for children. Papert (1980) claims that children who learn to explicitly teach the computer to do something learn more about their own thinking.

LOGO is a growing family of computer languages. The language is interpretive, which means it can be used interactively. This design feature provides early and easy entry routes into programming for beginners who have no prior mathematical knowledge. This ease of entry is facilitated by "Turtles," concrete and manipulatable objects (cursors on a computer screen, robots on the floor) which carry out instructions in very visible ways. Characteristic features of the LOGO family of languages include procedural definition with local variables that permit recursion. Thus, in LOGO, it is possible to define new commands and functions which then can be used exactly like primitive ones.

Papert accompanies his belief in computer programming as a learning environment in which children will enhance thinking powers and transfer their rigorous thinking from one domain to another with a philosophy of education. Central to this philosophy is his belief in self-guided "discovery learning." He maintains that students can learn to program without an explicit curriculum and without direct instruction from teachers. The LOGO programming language is so powerful that students are led to discoveries about its internal structure and become aware of their thinking without a specific sequence of curricular steps. In support of his claims, Papert and his colleagues (1979) provide examples of children "spontaneously" discovering the effect of varying numerical inputs, breaking problems into parts, combining sub routines into procedures or superprocedures, which provide support for the idea that students learn general problem solving skills by learning to program.

The power of LOGO and the persuasiveness of Papert's claims have led researchers outside the MIT LOGO group to investigate more systematically whether learning to program promotes the development of problem solving skills and whether people are able to transfer their problem solving knowledge to other domains. Pea and Kurland (1984) compared the activities of several groups of students, some of whom had participated in LOGO programming courses, on tasks that required planning. One task required the students to organize the most efficient plan for completing a set of classroom chores, such as watering plants, putting away chairs, cleaning chalkboards. The second task included a microcomputer program that enabled students working with the experimenter to design and check their plans interactively and a graphics interface that enabled the students to see the plans enacted in a realistic representation of the classroom.

Pea and Kurland found that students who had one year of programming did not differ from same-age controls who had not learned to program on various developmental comparisons of the effectiveness of their plans or their processes of planning. Students who had learned to program neither used the cognitive skills alleged to be developed in LOGO to organize a more efficient chore-completion routine, nor made better use of available feedback aids provided in the planning environment. They conclude that there does not seem to be any automatic improvement of planning skills from learning LOGO programming.

They considered various explanations for their findings. After dismissing potential objections to the inappropriateness of their planning tasks, they considered LOGO itself. They report problems with the LOGO programming environment as a vehicle for learning. The LOGO "discovery learning" pedagogy is insufficient, they feel, for the development of generalizable planning skills. This is really a complaint against the "learning without curriculum" approach that Papert advocates. From their perspective, learning how to plan is not intrinsically guaranteed by the LOGO programming environment. It must receive support from a structured context, including teachers (who, tacitly or explicitly, foster the development of planning skills), examples, models, student projects and direct instruction.

Their findings are consistent with other studies examining transfer of cognitive skills from one domain to another. It is notoriously difficult for people to spontaneously recognize the connection between problem isomorphs— problems of identical logical structure but with different surface forms— and to apply problem solving strategies learned in one context to another context (Wason and Johnson-Laird, 1972; Gick and Holyoak, 1980; LCHC, 1983; D'Andrade, 1984). It is clear that the similarity of the training task and the target task is not, in and of itself, sufficient to induce spontaneous transfer.

When transfer does occur, it seems to be when certain environmental conditions are in place. Naming the problem solving situations, providing direct instruction and practice, labelling the strategies, explicitly stating the relationships between two problems are some verbal mechanisms that can induce transfer (LCHC, 1983: 339). While transfer can be induced by explicit verbal instruction, it can not be said that transfer is occurring spontaneously. An overwhelming amount of our daily life is routine. We perform the same actions, in the same order, day after day. We have seen the same "problems" many times before. When we repeat the "solution" to these problems day after day, the connection between problem and solution becomes deeply ingrained. The problem of transfer is minimized, often dissolved entirely, when similar problems are repeated over and over (Lave, 1979).

In sum, special circumstances seem to be needed in order to facilitate transfer: (1) intense and systematic instruction on problem solving strategies, (2) the transfer situation needs to be so much like the learning situation that people do not even notice that they are transporting knowledge from one situation to another, (3) the similarity between the transfer and learning situation is marked, labelled or formulated.

Arranging a Classroom Environment for Teaching Problem Solving

Rowe arranged the learning environment in his classroom so that these conditions favorable for transfer were present. He engaged in the direct instruction of problem solving through a curriculum dubbed "the Problem of the Week" (to be explained below). He gave his students systematic and repeated practice in the use of problem solving strategies. He arranged two problem solving environments that had many surface features in common, one within the regular classroom and one within the LOGO lab. He provided verbal labels and formulations of the problem solving apparatus for students' use.

In this section, we describe (1) the approach to problem solving that Rowe taught his students (2) the manifest and redundant cues he provided his students so that they would recognize the situation in which problem solving strategies were to be applied and (3) the teaching/learning situation in the LOGO lab.

The General Problem Solving Plan

Rowe provided direct instruction in the approach to problem solving taken by Polya (1957), Souviney (1981), Charles and Lester (1982), among others, stressing a framework within which students can develop and use the specific skills and strategies needed to solve problems efficiently.

Polya (1957) specified a heuristic designed to pinpoint the learning process behind intuitions regarding problem solving. He proposed that certain kinds of problems can be attacked by applying a sequence involving four steps:

1. understanding the problem
2. devising a plan by choosing a problem solving strategy
3. carrying out the plan to find a solution to the problem
4. testing and generalizing the problem solution

In short, this approach identifies a small set of standard guidelines and suggests that the guidelines can be applied as strategies to solve problems effectively.

Marking Problem Solving Time

In order to teach students problem solving strategies, Rowe established a classroom atmosphere where problem solving became a daily routine. Students were immersed into this environment by a number of procedures which the teacher instituted and employed on a regular basis.

Establishing a regular time for problem solving. Rowe set aside a portion of each school day for problem solving. This time was called "The Problem of the Week." This period of the school day was explicitly marked, both in writing and verbally. The period of the day devoted to the "Problem of the Week" was posted on the classroom schedule along with language arts, social studies and other curricular topics. Thus, students were encouraged to see problem solving as a curricular topic equal to other subjects. The Problem of the Week was formulated at the beginning of the instructional period. The posted time was reinforced verbally: "OK kids, get ready for the problem of the week", or "get ready for problem solving time."

Visual reminders. The verbal formulations of the problem solving routine were reinforced by information posted around the room. One bulletin board in particular was devoted to problem solving. Posted on it were the steps in the problem solving routine and suggestions about the strategies to be used when attempting to solve problems. The bulletin board served as a visual reminder of the problem solving strategies being taught.

Explicating the Problem Solving Routine. The teacher presented problem solving lessons to the class as a whole, discussing the various skills one would use to solve the problem with the students. After a discussion of the problem solving activity, the students worked on the assignment alone or together with other students. The students were allowed to move around the room when forming work groups.

Teaching Problem Solving with LOGO

In addition to teaching a 6th grade class, Robert Rowe was responsible for the school's computer lab which was in the room adjacent to his classroom. When he took his sixth graders to the computer lab, he used LOGO as an environment in which students were to apply the problem solving strategies that they had learned in the classroom. This was a reversal of the relationship between programming and problem solving. Students are generally taught the LOGO programming language and are expected to develop problem solving skills from this experience that can be transfered to new environments. Rowe taught his students problem solving in the problem of the week curriculum, and used LOGO as the transfer environment.

Rowe's decision to use LOGO as a problem solving environment came from his dissatisfaction with the conventional way of teaching LOGO. He wanted to test a different approach. The conventional approach, as found in Papert (1980) and Papert et al (1979), is additive or what Levin (personal communication) calls "compositional." Students are introduced to fundamental commands, such as FORWARD, RIGHT, LEFT. As they master these simple commands, they are introduced to more complicated ones, e. g., REPEAT, EDIT MODE, VARIABLES, which they add to the elementary commands in a building block fashion. When a sufficient number of elementary commands have been mastered, students are able to construct geometric shapes such as boxes, triangles or houses. After the construction of geometric shapes has been mastered, students are moved on to more sophisticated matters, such as sub-routines and superprocedures, editing and debugging, control of continuous processes with loops, variables, conditions, stop routines, and recursion.

The different approach that Rowe wanted to implement is holistic and what Levin calls "decompositional." Instead of having students begin with small building blocks and compose a final product from the elements, the holistic approach presents students with a complete entity and asks them to explore, manipulate, analyze and modify it.

In order to compare the compositional and decompositional approaches to LOGO, Rowe divided his class into two groups for instruction in the computer lab. Students were assigned to the groups primarily for pedagogical purposes which influenced random sampling. Students were split up according to schedules restricted by band, their prior LOGO/computer experience, and any district classification. For example, if four students were classified as GATE, two each were randomly put into "Group A" (which was taught using the decompositional approach to LOGO) and two each were assigned to "Group B" (which was taught using the compositional approach to LOGO). If eight students were brand new to LOGO, four girls and four boys, then two girls and two boys were assigned to each of the two groups.

Learning the Basics. After pretests (to be explained below) were administered, the students were divided into the compositional and decompositional groups (described above) for instruction in the computer lab. Rowe then spent six weeks teaching the basics of computer literacy and LOGO programming.

Group A and Group B were taught the same material but at different times and with a different emphasis. Rowe presented the students with instruction in three sections: (1) basic information, (2) an activity to be modeled or recreated and (3) a self directed activity. The first section introduced the students to basic LOGO commands — e.g., DRAW, FORWARD (FD), GOODBYE. The students were expected to familiarize themselves with these commands by attempting to use them. The second section presented an activity e. g., a drawing or commands plus a drawing which the students attempted to recreate. The third section challenged the students to attempt a more complex design drawn on a worksheet.

The instruction surrounding the presentation of this information was similar except for a subtle emphasis on strategy. Group A (the "decompositional group") continued to receive explicit instructions emphasizing the problem solving strategies taught in the classroom to all students. When queried by students in Group A, the teacher suggested using the basic information (commands) as a strategy. The students were encouraged to take a given command and look for ways to apply it to the drawing or relate it to other commands in order to recreate the drawing in section two. The "compositional" group, Group B, was instructed according to the discovery learning approach recommended by Papert (1980). This group received suggestions to use the commands to build up a copy of the object they were presented.

The students in Group B were encouraged to compose a drawing out of the essential building blocks while the Group A students were encouraged to identify the building blocks within the drawing and look for relationships between the blocks before attempting to recreate the drawing. After students worked on worksheets to become familar with LOGO commands, they began working on projects. The presentation of each new project allowed the teacher to re-emphasize the teaching technique for each group.

Measuring Student Performance.

Several assessments of the student's problem solving abilities were made for the problem of the week domain and the LOGO domain. Pretests were administered in October and posttests were administered in June.

The Heath Test. We used six problems from the Heath Math Program to measure students' learning and transfer of problem solving strategies in the problem of the week domain. The problems and the type of strategy they tested are:

(1) "The Line Up" is a permutation problem
(2) "Tangle of Triangles" is a visualization problem
(3) "A Raft of Rectangles" is a combinations problem
(4) "The Staircase Case" is a math operations problem
(5) "A Balancing Act" is a process problem
(6) "Don't Fence Me In" is a math operations problem

The LOGO domain was assessed by two tests: one specifically calling upon LOGO knowledge, the "LOGO Knowledge Test", and the other requiring the student to demonstrate and use more general mathematical knowledge (the Brookline Test).

The LOGO Knowledge Test consisted of six problems designed by the classroom teacher to test the students' knowledge of LOGO and its environment. Problems one and two required visualization and translation between a given shape and the commands to produce it and vice versa. Problems three, four and five required visualization of spatial relationships. Problem six required remembering specific LOGO commands.

The Brookline Test (Papert et al., 1979) measured students' understanding of background math knowledge assumed to be necessary for programming in LOGO. The test consisted of four problems. Problems one and two were visualization problems requiring estimations of line length and angle size. The third problem required translating directional moves into math operations. The fourth problem involved planning how to get from one point to another - a process problem. Thus, three of the five problem solving categories are represented in this test.

Problem Solving Notebooks. Students recorded their problem solving work in notebooks. As might be expected from thirty six 6th graders, not every problem introduced to the class found its way into every student notebook. The problems on which we managed to collect complete data fell into the following categories:

1. combinations—e.g., problems where order is not important
2. permutations—e.g., problems where order is important
3. visualization—e.g., problems using symmetry
4. math operations—e.g., additive problem isomorph
5. process—e.g., problems where the optimum strategy is important

Scoring the Problems. The students' work on the problem solving tests and in their notebooks was scored based on the steps of Polya's heuristic discussed earlier.

1. understanding the problem by being able to state the goal and conditions expressed in the problem statement.
2. devising a plan by choosing a strategy for solving the problem.
3. carrying out the plan to obtain an answer.
4. evaluating the answer.

Each step was scored from zero to two points, for a total of eight points on any problem. We were interested equally in the answer that students obtained and the process by which they arrived at their answers.

We examined the data for indications of change over time in the students' ability to apply the problem solving heuristic as evidenced by their ability to concretely state their goals, conditions and strategies. It was expected that increased facility at explicitly stating such information would lead to a more systematic and complete demonstration of the work done to obtain an answer.

Rowe's teaching arrangement, in which he taught problem solving in his classroom and in his computer lab, enabled us to make a number of observations about the effectiveness of explicitly teaching problem solving strategies to students. First, we compared the students' acquisition and use of problem solving strategies within the problem of the week domain. Here the issue was whether students learned the problem solving strategies and applied them with increasing skill to the new problems that were presented to them each week. Second, we examined students' acquisition of LOGO knowledge and more general skill within the LOGO domain. Third, we examined students' performance in the computer lab. Here we compared students who were taught LOGO by the decompositional approach and the students who were taught LOGO using the compositional approach. This difference in instruction was expected to effect student performance on the two tests. The compositional group (Group A) was expected to perform better on the Brookline test because it tested more general problem solving skills, and the decompositional group (Group B) was expected to perform better on the LOGO test because it tested basic programming knowledge.

Results

The Development and Transfer of Problem Solving Strategies

The problem solving curriculum conducted within the classroom consisted of problems which required the use of different problem solving strategies and had varying degrees of difficulty. The students were given one problem solving period of 20-30 minutes to work on each problem from the Heath Pretest. The teacher collected the worksheets at the end of a period and returned them to the students the next day. Evidently, some students did not turn in their worksheets at the end of a period and could not find them at the beginning of the next period. The teacher gave these students a new worksheet; however, this situation left us with incomplete data in some cases.

The Wilcoxin test (Siegel, 1956) was used to test the null hypothesis, i. e., that there would be no change in performance on these problems due to the explicit teaching of problem solving strategies during the school year. The results of this test indicate that we may reject the null hypothesis for five of the six problems at $\alpha < .01$. On all problems except the visualization problem (#2) the students showed significant change in performance during the school year. The surface features of this problem appear to have created confusion for the students who did not score well on either the pre or post test.

Table 19

Students' Performance on Heath Pre and Post Tests

Test Question

	#1		#2		#3		#4		#5		#6	
	Pre	Post	Pre	Post	Pre	Post	Pre	Post	Pre	Post	Pre	Post
N =	33	23	33	23	31	22	31	23	25	24	25	24
Median =	2	3	2	3	2	5.5	2	4	0	4.5	0	.5
Gain =		+1		+1		+3.5		+2		+4.5		+.5

The other problem that was difficult to interpret was a math operations problem (#6) involving the relationship between perimeter and area. The students did not recognize a way to approach this problem and many wrote on their papers "I don't understand" or "I don't know how to do this," even at the end of the school year. Eight of the sixteen students were unable or unwilling to attempt this problem on both the pre- and posttest. Seven of the other eight students who attempted the problem on the posttest did not do so on the pretest. The eighth student attempted the problem but had no real understanding of it. Despite these peculiarities in the scoring system, the Wilcoxin test indicates that the gains made by these eight students were statistically significant (α =.01).

We also selected two sets of problems from the problem of the week curriculum to measure students' learning of problem solving strategies. The problems we chose were problem isomorphs, that is: they had the same logical structure but had a different surface form (i.e., wording). The problem isomorphs we will discuss here are: (1) the process isomorph and (2) the commutative isomorph.

Process Isomorph. The process problems presented students with eight objects (baseballs in one and eggs in the other), all similar in appearance, and asked them to find the lighter or heavier object in only two weighings using a pan balance. The baseball problem was presented in October and June and the egg problem was presented in March.

Table 20

Students' Performance on Process Isoporph Problems

	Problem		
	BB (Oct)	Egg (March)	BB (Jun)
N =	25	20	24
Median =	0	5	5
Gain =		x= +5	y = +5

key: x = October to March y = Oct to June

The students showed significant growth in their ability to do this type of problem during the school year. There was significant improvement by the entire class from October to March and October to June [Wilcoxin (α=.02)].

Commutative Isomorph. The commutative problems embed an algebraic principle into the problem. The commutative principle (a+b=b+a) represents an abstraction of a mathematical concept which students find in math word problems and drills of math facts.

Our analysis focused on the "water fountain" problem and the "gold digger" problem. The water fountain problem, which made its appearance in November, asked the students to measure 6 liters of water from a fountain using only two cans of 7 liters and 11 liters. The goal was to arrange a set of measurements which would produce the desired amount of water in one of the larger cans. The gold digger problem, done in February, asked the students to identify the weight of various gold nuggets using a pan balance and three weights of known amounts: 1, 3 and 9 grams. The goal of this problem was to arrange a set of measurements which would enable a number of gold nuggets of unknown quantity to be weighed up to the maximum amount possible (13 grams).

Table 21

Students' Performance on Commutative Problem

	Problem Name	
	Water Fountain	Gold Digger
Month Given	Nov	Feb
N	14	20
Median	5	5
Gain =		+0

While the median score remains the same, students' performances appear to increase from the water fountain to the gold digger problem; however, the sketchiness of this data does not yield results which are statistically significant.

It is interesting to note that only two of the twelve students showed any performance loss, and this loss was minimal (-1 gain score). One student's performance is especially interesting because it highlights the fragility of the learning process which teachers must support. This particular student arrived at the correct answer for the water fountain problem but, followed an inefficient, circuitous route indicating incomplete understanding of the optimum strategy. Later, when attacking the gold digger problem, this student used the optimum strategy. She did not get credit for the correct answer, however, because two of the measurements are left off her worksheet which produced the small performance loss.

In sum, these improvements make us optimistic that the direct instruction of problem solving strategies is responsible for students' learning and the transfer of this knowledge to new situations. However, we must remain cautious. The complexity of data drawn from a naturally occurring setting must temper enthusiasm for this interpretation.

Developing LOGO Knowledge

LOGO Problem Solving. Students showed improvement on three of the four Brookline test problems from the pre to the posttest. The students'median performance improved on all problems but one. The Wilcoxin test allows us to reject the null hypothesis for 3 of the 4 problems ($\alpha <$.05, .05 and .02). However, this fourth problem contained sixteen of the thirty-four possible points. Therefore, while students' performance was in the predicted direction, it is not surprising that the results are not statistically significant.

Table 22

Students' Performance on Brookline Test

Test Question

	#1		#2		#3		#4	
	Pre	Post	Pre	Post	Pre	Post	Pre	Post
N =	34	30	34	30	34	27	34	29
Median =	9	9.5	4.0	3.5	4	5	1	1.5
Gain =		+.5		-.5		+1		+.5

The math operations problem (#3) was given closer analysis because it is similar to the water fountain and gold digger problems. This problem asked the student to translate a series of forward and backward steps into a one directional step.

To solve this problem, the students need to link forward steps to backward steps—i.e., forward steps require addition and backward ones subtraction. Once they perceive this relationship, carrying out the actual process and reordering of information to arrive at the correct answer was quite elementary for most of these students. In fact, ten of the twenty five students scored the maximum points possible on both the pre and posttest. The students showed significant growth over the school year [Wilcoxin (α=.05)].

LOGO Knolwedge. The results of the LOGO test indicate that the students' knowledge of LOGO increased from the beginning of instruction to the end on both the overall test and each of the six individual problems.

The median score of the class as a whole gained 12 points from November to June.

Table 23

Students' Performance on LOGO Knowledge Test

	Test Question											
	1		2		3		4		5		6	
	Pre	Post	Pre	Post	Pre	Post	Pre	Post	Pre	Post	Pre	Post
N=	32	29	32	29	31	29	31	29	31	29	31	29
Median =	2	4	2	4	1	4	1	4	0	3	0	1
Gain		+2		+2		+3		+3		+3		+1

Compositional and Decompositional Approaches to Problem Solving

To determine whether students who were taught LOGO emphasizing the discovery learning approach (compositional group) differed from students who were taught emphasizing problem solving strategies (decompositional group), the performance of Group A and Group B on the Brookline and LOGO Knowledge Tests were compared.

LOGO Knowledge. We expected Group B to perform better than Group A on the LOGO Knowledge Test because it assessed specific LOGO skills which were a part of that group's explicit instruction. The results were in the predicted direction. Group B gained 12.5 points on the LOGO test while group A improved 11 points. The results obtained by Group A on this test deserve further comment. They made an improvement which was greater than expected. This improvement suggests that students can learn specific LOGO commands when programming information is embedded within a broader framework of students' instruction.

Table 24

The Performance of Group A and Group B on the LOGO Knowledge Test

	Group A		Group B	
	Pre	Post	Pre	Post
N =	15	16	16	13
Median =	5	16	6.5	19
Gain =		+11		+12.5

LOGO Problem Solving. We expected Group A to show more change than Group B on the Brookline test because this test assesses students' application of problem solving strategies. The results were in the predicted direction; Group A increased by 3 points while Group B showed no gain. While this difference was not statistically significant, the results suggest that Group A students transfered their problem solving skills from the classroom to the LOGO lab.

Table 25

Group A and Group B Performance on Brookline Test

	Group A		Group B	
	Pre	Post	Pre	Post
N=	17	15	17	11
Median =	19	22	18	18
Gain =		+3		+0

Students' Work While Solving Problems. The idea that students would transfer an understanding of the problem solving heuristic from the problem of the week curriculum to the LOGO tasks also receives support from anecdotal evidence about students' work while solving problems. One piece of evidence relates to the students LOGO notebooks. The two groups began a series of projects which were to be planned and recorded in their notebooks. Although neither group of students was totally successful in its planning or record keeping, some differences were observed.

The students were encouraged to write down the commands, procedures and routines they were trying to use in their projects. This information was then tried out using the DRAW mode of LOGO. If the visualized pattern did not match the turtle drawn pattern, then the student was to make changes and adjustments before storing the information permanently on disk. Group A students tended to "outline" their projects by nesting procedures within procedures. Using this approach the students first decided on the main procedures, then moved inside one such procedure and worked on its subprocedures. This organization was extremely productive for pairs of students who cooperated well with one another. After the initial planning, they divided up the work in various ways and used their computer time efficiently.

Group B students tended to use their notebooks merely as a record keeping device after trying out an idea on the computer in the DRAW mode. If the attempt was suitable, a procedure might be defined; if the attempt was unsuitable, the students continued drawing and recording their moves until the screen version was suitable. One pitfall frequently encountered using this method was inefficient visual to spatial translation of images — e.g., overdrawing or underdrawing. Students compensated for such errors by moving forward or backward as needed or changing the angle by increasing or decreasing the size of the image. Even though they recorded these movements in their notebooks, few students recognized the math operations—addition or subtraction—embedded in these moves. As a result, they rarely recombined the several moves into only one move. Most frequently, when ready to transfer their notebook notations into a defined procedure, the students copied the information without making any changes. As students became facile with the DRAW mode and translating their visual images into spatial commands, they tended not to record on paper at all, allowing the computer to do this work. In effect, this served to block their ability to see the relationship between commands or to utilize any problem solving strategy other than trial and error.

This informal assessment of students' work while in the process of solving problems suggests that the compositional approach neither helped students develop efficient and systematic planning techniques nor invited them to transfer the paper and pencil strategies learned as part of the classroom problem solving curriculum.

Conclusions

The work in this chapter was addressed to the following questions:

(1) Does the direct instruction of problem solving strategies lead to improved problem solving by students?

(2) Do problem solving strategies transfer between situations when the environments are closely matched and the use of the problem solving strategies has been verbally marked and formulated?

(3) Do students who have been taught a programming language (LOGO) using a decompositional approach use problem solving strategies better than students taught this same language using a compositional approach?

Based on test results, we feel comfortable concluding that students who receive intensive and systematic instruction in problem solving and have the problem solving apparatus formulated for them explicitly can learn problem solving strategies and transfer them to new problems that have a similar logical structure with varying surface features.

We are also encouraged by our results concerning the utility of the decompositional and compositional approaches to teaching a programming language. The students who were taught LOGO by the decompositional approach did better than students who were taught using the compositional approach on a general problem solving test, while students who were taught LOGO by the compositional approach did better than students taught by the decompositional approach on a test of LOGO knowledge. Both of these test results are in the direction predicted by the assumptions underlying the compositional and decompositional approaches. Students taught by the decompositional approach seemed to approach programming problems differently than the students taught the compositional way. The decompositional group planned their products in advance while the compositional group treated their notebooks as record-keeping devices after they completed their work.

Implications for Further Study.

It is best to view this work as a pilot study. Our intuitions about the way to study problem solving in naturally occurring situations need refinement before solid conclusions can be drawn. While we will want to make changes in research design and data gathering in future studies, we will want to keep the problem solving activity itself in the naturally occurring context of the classroom for a variety of reasons. The most notable reason is that we want to be able to test the generality of the problem solving heuristic.

The appeal of the problem solving heuristic is that it may be applicable to diverse situations which go far beyond classroom math problems and computer projects which provide the data for this research. Such a framework to learning assumes that our task as educators is broader than the transmission of specific knowledge, even when that knowledge involves abstract concepts. Rather, the task involves critical thinking and abstracting generalizable relationships from specific knowledge.

Dynamic Support for Problem Solving. Teaching problem solving to children requires a rich, supportive environment. In the conventional approach to teaching a problem solving task such as LOGO, all the parts are available, but the sense of the whole and instructions for putting the parts together are often missing. The decompositional approach to LOGO adopted here provided an alternative form of supporting the students' learning. In a decompositional approach to problem solving, teachers present the entire task to the students and provide the expertise to accomplish the task with decreasing amounts of support.

The "nominal" task is located on several planes. The teacher has a learning activity which represents part of a pedagogical class of activities. The students also engage in the learning activity; however, for them the task is more specific or concrete—i.e., a set of behaviors.

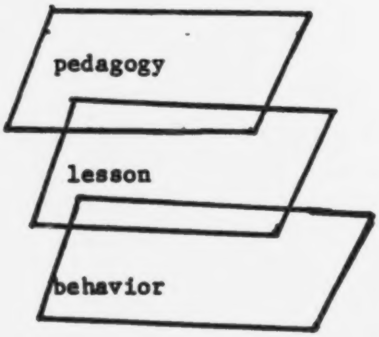


Figure 14: Planes of Pedagogical Activity

The promise of the decompositional approach to teaching the problem solving heuristic lies in the fact that it can help us capture ethnographically the thread which links all three planes of activity. By looking at both the teacher's performance and the students' performances, we trace the thread of underlying competence as it moves from the intersubjective plane (Teacher -Student interaction) into the intrasubjective plane (Students' reflexive interaction).

Collecting process data. The use of field notes to collect data about how students approach problems was problematic since the ethnographer could not capture everyone's ideas simultaneously. Attempts to videotape students describing their problem solving process were problematic for the same reason. In future research, we plan to have the students write in their problem solving notebooks about the process they were going through. Such a writing activity could be integrated into the language arts curriculum of the classroom. In fact, a computer generated file could be used to support the note taking activity, thereby broadening the set of computer related skills learned by the students to include word processing (Souviney, personal communication). The "self report" data would facilitate access to the problem solving processes and students' commentary on their thinking.

Constraining the Problem Solving Domain. Problem solving research can be approached by attending to two process factors: (1) the difficulty of the problem and (2) underlying problem isomorphs. The usefulness of these two factors is that they allow the researcher to trace changes in individuals and classrooms across time.

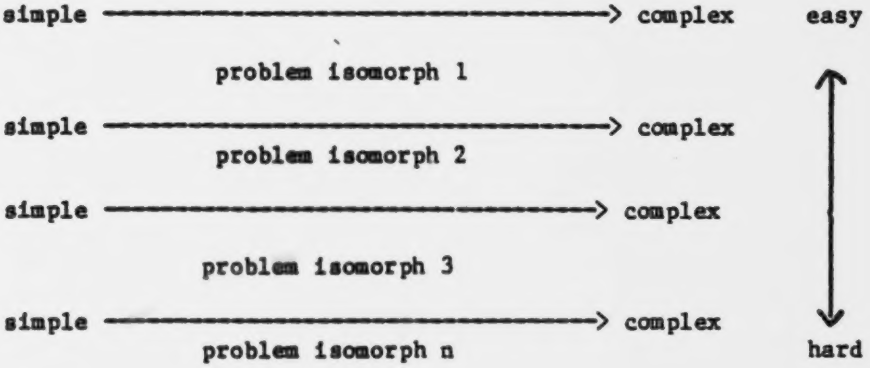


Figure 15: The Dimensions of Problem Isomorphs

The application of this rationale makes the research quasi-experimental within the natural setting and provides a set of expectations (loosely akin to hypotheses) of what will emerge from the ethnographic data. Explicitly teaching the problem solving heuristic (e. g., procedures for being systematic and complete, and concepts such as efficiency and symmetry coupled with feedback to the students on their attempts) can provide an environment where the learning of specific problem solving skills and their transfer to novel situations can be investigated. Learning to abstract information from a given situation and recognize new situations where that information applies represents a "metacognitive" skill which many people think is important our complex technological world. Discovering motivating and relevant ways to provide this type of education for students remains an ongoing concern for educational research.

We feel that further study requires careful staggering of the problem types in order to assess change. Thus, we would organize a rotation for the problems—e.g.,

	Sept	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May
type	1	2	3	4	5	1	2	3	4

With the focus on a specific problem type, there would be explicit instruction on the optimum strategy for that problem. This would provide the environmental support for learning these strategies and make them available for trasnfer to new situations.

Another approach would be to provide a curriculum which approaches all of these problem categories at the same time but varies each on level of difficulty. Presently tum Suden is attempting to integrate these two features (the problem isomorphs and the staggering of problem types) through a computerized individual instruction program in an after school setting. This current work allows the student freedom to chose the problem thereby enabling students to gain control over their work. In this approach to teaching and studying problem solving, once a problem is selected, the student shows mastery of the optimum strategy before moving onto a more complex isomorph in that problem category. The computer's ability to save work on disks allows students to review their work when approaching a problem in more than one session. We would use this information to supplement the information we gather from the problem solving notebooks.

CHAPTER 9:

SUMMARY AND CONCLUSIONS

Hugh Mehan, Luis Moll and Margaret M. Riel

We see three main problems with the current uses of microcomputers in education: (1) the educational potential of microcomputers is underutilized by the current emphasis upon programming and computer aided instruction (2) access to advanced uses of microcomputers is stratified; low income and linguistic minority students do not receive instruction which is equivalent to their middle income and linguistic majority contemporaries; and (3) an undue emphasis on computer programming in computer literacy curricula is ill preparing students for the world of work in an information society.

Our modest approach to addressing these issues has been directed toward exploiting a wider range of the microcomputer's capabilities with a diverse population of elementary school students through collaboration between elementry school teachers and university researchers. We are trying to make changes and improvements in schooling by teacher-researcher collaboration because teachers are in the closest contact with students and computers. This particular collaboration involved the systematic introduction of computer curricula in four classrooms accompanied by supporting knowledge and training. The computer curriculum, implemented in language arts and mathematics, was an extension of previous work conducted at UCSD to teach basic skills to small groups of special education students in resource rooms and after school clubs (LCHC, 1982; Riel, 1983; Levin et al, 1984). In this research project, we extended these educational efforts to a more diverse population of students, to the constraints of a regular classroom configuration and standard educational curricula.

The classrooms had diverse student populations in terms of age, measured ability, socioeconomic background and ethnicity. The students were in grades 2-6; their ability was measured from the lowest CTBS quartile to qualification for the GATE program. One classroom was part of a designated bilingual program, two others had a number of students who spoke Spanish as a first language and one was designated as a Chapter 1 classroom.

Mutual Influences Between Microcomputers and Classroom Organization

We wanted to know whether teachers use time and space differently and make modifications in what they teach and how they teach as a result of having a microcomputer available for instruction.

Impact on Spatial and Temporal Arrangements

There was no significant change in the way in which the teachers arranged the space and used time in their classrooms when they had a microcomputer available for instruction on a full time basis. The teachers who had used learning centers extensively in previous years used this spatial and instructional configuration when a microcomputer was made available to them by our project. The teachers who used whole group methods of instruction in previous years continued to teach their classses in this manner when the project made a microcomputer available for their use.

The absence of changes in temporal and spatial arrangements observed when microcomputers were introduced into classrooms shows how resilient classrooms are to attempts to change (Sarason, 1982; Cuban, 1983). If the results of this modest investigation are replicated in other school settings, we should not be surprised if microcomputers continue to be inserted into existing classroom arrangements (Michaels, 1984) and do not lead to wholesale changes in classroom organization.

While the introduction of a microcomputer for the purposes of instruction did not modify existing spatial and temporal arrangements in the four project classrooms, the availability of a microcomputer added a new dimension of participation to the classrooms. Each of the teachers in this project decided to have two students work at the computer at one time.

Dyadic peer interaction was the new "structure of participation" (Philips, 1982) that emerged when two students were placed together to work at the computer. Students were given assignments for work sessions at the computer by the teacher, either verbally at a whole-group orienting session, or in writing at the computer center itself. Students worked together on the assigned activity carrying out the teacher's assignments without direct adult supervision. When they had difficulty with computer operations, they often called to the teacher for help. However, the teachers' response was to encourage the students to use each other as resources, consult the written instructions around the computer, or to go to other students for assistance.

The teachers did not dictate a particular form of interaction to the student pairs. They were left to their own devices to sort out the manner in which the task would be completed. In that sense, the students' participation in the computer activity was voluntary, not compulsary. While they were responsible for completing their assigned session at the computer, the details of how that session would be completed was left to the students. Since the teacher did not monitor the students at the computer directly, their work was not evaluated moment-to-moment or publically, as it so often is in regular classroom lessons (Mehan, 1979).

As a consequence of this additional participation structure, students developed a different sense of social relations. The students assisted each other at the computer in ways that were productive. They often corrected each other's mistakes and cooperated in the completion of assigned tasks. Dyadic peer interaction also provided social resources which facilitated learning. In language arts activities, even when neither student began an assignment with an idea of what to do, the discussion of the problem often presented the students with the way to proceed. In the process of entering text, the student who was typing was often concerned with such local issues as the spelling of a word, while the other student concentrated on more global issues such as the construction of the essay and coherence among sentences.

Impact on Curriculum

The Computer as a New Means to Meet Previously Established Curricular Ends. Three of the teachers entered the project approaching Language Arts instruction from a perspective that integrates the teaching of reading with the teaching of writing. By emphasizing the writing process (Cooper and Odell, 1978), these teachers used the text that students wrote to create opportunities for students to read. In turn, texts that students wrote became a basis for later reading.

The computers were thoroughly incorporated into the instructional plan of the language arts curriculum. The teachers planned for computer activities in the same manner that they planned for other instructional activities. The computer was not an isolated piece of educational technology that students were taught about. It was a functioning part of the classroom environment and was used as frequently and in the same way as tables, chairs, typewriters, tape recorders, paper, pencils, chalk and chalkboard.

The teachers organized tasks for the microcomputer that were coordinated with tasks that were carried out in other parts of the curriculum. Reading and writing activities that were taught using paper, pencils and chalkboards were coordinated with activities that were taught using the microcomputer. A poetry writing activity begun with paper and pencil, for example, was extended to the computer center where a similar writing activity took place. In this role in the language arts curriculum, the microcomputer was a new _means_ to meet previously established educational goals.

The Computer as a Means to Meet New Curricular Goals. The availability of a microcomputer facilitated a new social organization for reading and writing. It is at this juncture that the microcomputer moved beyond its role of providing a new, albeit dynamic, means to reach previously established goals, to providing a medium through which new and previously unattainable educational goals can be reached.

The teachers introduced a student newswire service known as the

"Computer Chronicles" in their classrooms. Students at a variety of distant sites exchange newspaper articles they have written as well as ones written by students in the network to produce local editions of the Computer Chronicles newspaper.

The Computer Chronicles helped the teachers establish learning environments which were organized for communicative purposes and not just as an exercise for teachers to evaluate. The presence of an audience for writing, in the form of classmates, parents and peers in Hawaii, Mexico and Alaska, was a crucial ingredient in giving students a purpose for writing. This writing for a purpose and not "just writing" or even writing on the computer, subordinated students' concern for the mechanics of writing to the goal of communicating clearly .

The presence of changes in teacher-student relationships and curriculum in conjunction with absences of changes in classroom organization leads us to consider two types of accounts about the impact of computers on education. One proposes that classroom culture will dictate the organization of classroom computer use; the second says that the availability of microcomputers will cause wholesale changes in education. We are inclined to dismiss both interpretations as overstated and are more inclined to adopt the view that characterizes the relationship between classroom organization and computer use as a mutually influential one.

Some Consequences of Peer Interaction at the Computer

The teachers wanted their students to master the operation of the microcomputer and be able to use the microcomputer for academic tasks e. g., composing poems and solving problems. The teachers started the students' learning process at the computer in a decidely social manner: pairs of students worked together to accomplish assignments. This arrangement enabled us to examine whether pairs of students working together gain benefits that do not accrue to students working alone.

When pairs of students were placed together at the microcomputer, they cooperated in the accomplishment of the task by dividing the labor between them. Verbal interaction was a particularly important medium in these situations, because the students working together talked out loud to each other. The act of verbalizing material led to cognitive restructuring on the part of the students who were attempting to explain. Verbal interaction was also important because it led students to hear different points of view, which, in turn, lead to cognitive conflicts. The resolution of these conflicts required the students to examine their own understandings and to consider different viewpoints.

The students divided the task in two principle ways: sequential processing and parallel processing. It was by dividing the labor that students completed the task assigned to them by the teacher.

Pairs of students divided the tasks sequentially when they used software which prompted students to pick from pre-determined choices. Students either alternated access to the keyboard every time the machine provided a prompt or conducted a series of operations before turning the keyboard over to the other student. Students soon settled on the "story" as the turn-alternation unit. At this point, one student entered a complete story while the other student provided assistance in the form of comments and suggestions about technical operations of the program and the computer.

Pairs of students divided the task in parallel when they used software which enabled them to enter complete texts. While one student was engaged in entering text in response to general hints provided by the software, his or her partner was engaged in monitoring computer operations such as the use of the return or control keys and monitoring writing operations such as spelling, grammar, sentence structure and the overall coherence of the composition.

A general trend from sequential processing to parallel processing appears when the division of labor is examined across the whole school year, The most accelerated point of the transition occurred when the software changed from program controlled to user controlled. The shift from sequential processing to parallel processing seems to have been influenced by the design of the machine and the design features of the software that the students were assigned to use.

A Holistic Approach to Computer Literacy

School districts are developing entirely new curricula for teaching students about the operation of the computer. Many of the courses in computer literacy curricula teach machine operations separately and distinctly from the uses that the computer can have for academic and occupational purposes.

The teachers in this project taught their elementary school students about computer operations within the context of teaching them about computer uses, including writing and editing. Students spent on the average of 25 minutes a week in language arts and 25 minutes a week in mathematics at the computer. This means that they had 15 hours at the computer by the end of the school year. The students in these classrooms learned to write and edit using a microcomputer, and, they learned to operate the machine without a specific and special course designed to teach them about the machine.

If our modest results can be replicated, they have broad implications for teaching computer literacy. This study suggests that it is not necessary to develop a special, separate and independent curriculum called computer literacy. Instead, the teaching of machine operations can be embedded in the teaching of academic tasks. We have had some success placing computer operations within a language arts curriculum. The same principle should also apply to math, science and social studies.

In addition to being cost effective, the holistic approach to computer literacy takes advantage of the highly motivating characteristics of microcomputers (Malone, 1981). Students are exposed to information about computers while using them to learn important educational material. If computer literacy is decontextualized by having students learn about the computer without leaning what it can do, then the motivating elements can be lost. In so doing, we fear that computer literacy requirements can become yet another academic hurdle for students to jump over rather than being a meaningful educational experience in which usable skills are taught in understandable ways.

Computer programming plays a different role in this holistic approach to computer literacy than it does in many computer literacy courses. Instead of making computer programming the single entry point and pinnacle of computer literacy, we are suggesting that it is important to provide students with "multiple entry points to expertise" (Levin and Souviney, 1983). Multiple entry points enable students to use computers as powerful tools for a wide range of applications. For some students, that power will come first through learning to program the computer. But, for others, that power could and should come, we feel, from first learning how to use the computer, to write and edit text, to create music, graphics and animation to organize information and to communicate it to others. Furthermore, one avenue of access does not preclude another. Just as the student who begins learning about computers by programming them is not precluded from assembling spread sheets later on, so, too, the student who learns text editing first is not precluded from learning to program later.

Like other investigators of human-machine interface, we found that computer users consulted social resources more often than printed materials and manuals. There are lessons to be learned from these observations about the nature of instructions given to students who are learning to work at computers and the design of user guides.

While thorough users' guides and brief instructions must continue to be available to people learning to operate the computer, it does not seem to us that manuals should be the primary element in teaching. Instead, teachers can capitalize on the seemingly ubiquitous presence of local experts. In each of our classrooms there were students who were highly motivated and knowledgeable about computers; we are recommending that this expertise be systematically exploited by encouraging students who are learning about computer operations to seek out these "computer tutors."

It is also possible to empower students with knowledge about the computer. Diaz (1984) has been exploring this idea in an after school program in South East San Diego. He selects students who have been having academic difficulty or have not routinely enjoyed high prestige in the eyes of peers and gives them special knowledge about computer operations. Other students soon learn that they can obtain special help from these experts. The resulting transactions seem to have benefits; the students in need of help gain help, and the previously unsuccessful student now gains experience with success.

While calling for the systematic use of expert students in the computer center, we are not recommending the elimination of written instructions or manuals entirely. Particularly helpful are brief instructions which can be arranged around the keyboard and monitor. The project teachers started the year with general instructions about machine care and basic text editing commands. When they started a new activity, they posted specific instructions that were relevant to the new task on or near the computer. By the end of the school year, the computer was quite literally papered over with notes, reminders and penciled in notations. To a visitor or first time user, the computer and its paper cloak seemed imposing if not impossible to penetrate. But students, socialized into each new layer of activity with its accompanying instructions, seldom had difficulty in consulting the appropriate special note, even though it may have been buried beneath weeks of similar kinds of notes.

In addition to a brief list of generic commands and specific lists of instructions, our experience tells us that a different kind of instruction also needs to be posted at the computer center. Diagnostic instructions which take the discourse form of "if you have a problem, then do x" need to be available to students. The intent of diagnostic instructions is to encourage students first to initiate locally organized trouble shooting routines on frequently occurring problems, and second, initiate calls for social help in a prescribed sequence. Peers and computer tutors are to be consulted before teachers. Specifying the order of calls for social help is intended to lessen students' dependence on the teacher and foster student initiated actions.

Functional Learning Environments for Writing

The word processing systems that are available on microcomputers have been touted as possessing the solution to problems in writing (Lipsom and Fisher, 1983) because they facilitate the production of manuscripts. Printers are said to facilitate the writing process because students find the immediate production of neat, professional looking copy to be highly rewarding and motivating (Malone, 1981; Miller, 1984; Levin et al, 1982; Lipsom and Fisher, 1983).

We, too, are impressed with the utility of word processors and printers; however, we do not think that word processors *per se* are responsible for improved writing. In and of themselves, computers can not solve the problem of teaching students to read and write. While we have found that a microcomputer alone can not transform unskilled writers into skilled ones, it does help organize a medium that makes a new social organization for writing possible. The microcomputer works effectively in language arts when tasks that are organized for it are coordinated with tasks that are carried out in other parts of the curriculum (Mehan, Miller-Souviney and Riel, 1984). It is the creation of functional learning environments which utilize the computer as a tool to meet educational goals, and not the computer treated as a teaching machine that dispenses knowledge to students, which has positive effects on the writing process.

Functional learning environments, in which reading and writing were arranged for communicative purposes, gave students a goal for writing: to share their ideas and concerns with other students, some of whom were local, some of whom were distant. The public nature of writing provided motivation for re-writing and editing, giving students increased knowledge of word processing and control over the composing process.

Dynamic support provided by the interactive capabilities of the computer minimized the students' concern for the mechanics of writing and maximized attention to the flow of ideas and the process of writing, resulting in improved quality and fluency. By arranging learning environments in which computer based support was gradually removed, students gained control of writing by gradually assuming the parts of the task initially accomplished by the computer.

Students worked in teams to generate new articles or to edit those received from other locations. These cooperative working sessions facilitated the division of the newspaper writing task among the students. While one student concentrated on the mechanics of writing, another student concentrated on the generation of ideas. Cooperative working sessions also created a local audience for writing. The presence of another person during the writing process helped a student generate ideas and provided immediate responses to the written text.

While students in all classrooms improved their reading and writing skills beyond grade level expectations, the most impressive improvements appeared in the classroom taught by the skilled teacher who integrated the microcomputer into her language arts curriculum, had previous experience using computers and had prior experience teaching at grade level. Students in her classroom gained, on the average, 3 grade levels in language mechanics and 2 grade levels in language expression on standardized tests. Students did not improve as dramatically in classrooms where some of these features were absent (e. g., where there was a novice computer user, or the teacher was inexperienced teaching language arts as an integrated activity). Therefore, while it is difficult to say how much of students' improvement, if any, can be attributed to the computer alone, the results of our research suggest that a combination of features (computer knowledge, teacher experience, the integration of the computer into functional learning environments) had a positive effect on students' learning.

Computer Activities in a Bilingual Setting

We paid particular attention to the way in which the computer was introduced into the bilingual classroom because this setting had many of the features we would expect to find in many public schools: the teacher was recently assigned to teach at a new grade level, was participating in co-teaching pull-out programs for bilingual students, was learning a new method for teaching language arts and had a class composed of low achieving and LEP students.

The course of development of the integration of the computer into language arts activities was uneven. The first third of the year was spent establishing schedules and routines, modifying software and activities to accommodate younger and bilingual learners and providing students with lots of practice on machine operations. The modifications included providing many points of entry into the software systems and using social resources to assist the young learners, especially with the computer commands that were in English. Although mastering computer operations was particualrly difficult for the LEP students, the teacher did not reduce the level of instruction presented to them. Instead, she imported social resources, including older students from neighboring classrooms and members of the research team, to permit the students to engage in the tasks at the same level as the rest of the class. While this strategy proved to be laborious, it was effective. By December, the children, including the LEP students had overcome difficulties with procedural matters and were beginning to participate in computer activities profitably.

During the second third of the year the teacher learned to develop software in Spanish. The teacher's commitment to learn to program interactive texts in Spanish provided the LEP students with a significant, new entry point into computer activity. Instead of being a consumer of other's products, she became a producer of her own products. Programming, it seems, provided her with a sense of control over the technology, concrete ideas on what to do next, and allowed her to take better advantage of the specific resources found within and outside her classroom.

During this period the teacher also concentrated on a single computer based activity, "The Computer Chronicles." Not coincidentally, it was during this period the students' increased their skill in manipulating the computer and associated software. The students were able to do some text editing on-line and they collaborated readily to complete tasks assigned to them by the teacher. These changes were as evident in LEP as English monolingual students, indicating that the teacher was successful in helping both groups of students perform similar tasks at similar levels.

For the last months of the project, the classroom computer activities required the students to compose text and to modify their drafts on the computer. As in earlier times during the year, the students' progress through these activities was uneven; social resources were relied on heavily at the beginning of this period, and gradually receded in importance as students learned the editing and composing tasks.

The bilingual teacher's experiences with the computer are indicative of the experiences we'd expect to find when a novice computer user attempts to introduce a micromputer into a classroom composed of low achieving and bilingual students. The process was laborious and at times exasperating. The teacher had to go to great lengths to balance her interest in this novel device with her commitment to mandated curriculum. The students, especially younger and LEP students, developed computer expertise at a slower rate than students in the upper grades. The teacher's commitment to organize her classroom environment such that younger and LEP students engaged in comparable educational activities (albeit with increased social support) represented an impressive antidote to the tendency of providing reduced levels of instruction to under achieving students.

Teaching Problem Solving Strategies

The transfer of knowledge from one domain to another has been hard to detect. When transfer does occur, it seems to be when certain linguistic mechanisms operate or when specific environmental conditions are in place. Naming the problem solving situations, providing direct instruction and practice, labeling the relevent strategies, explicitly stating the relationships between basic and transfer problems are some of the verbal mechanisms that can induce transfer (LCHC 1983). Transfer can also be induced by rearranging the socio-cultural environment. An overwhelming amount of our daily life is routine. We perform the same actions, in the same order, day after day. When we repeat the same "solution" to these problems day after day, the connection between problem and solution becomes deeply ingrained, thus minimizing or disolving the problem of transfer entirely.

One of the teachers arranged the learning environment in his classroom so that these conditions for transfer were present. He provided intensive, systematic and direct instruction on problem solving strategies via a curriculum dubbed "The Problem of the Week." He provided verbal labels and formulations of the problem solving apparatus for students' use. He arranged two problem solving situations that had many surface features in common, one within the regular classroom and the other in the computer lab he taught. When he took his sixth graders to the computer lab, he used LOGO as an environment in which students were to apply the problem solving strategies they had learned in the classroom.

In addition, he divided his classroom into two groups for instruction in the computer lab, one a compositional and the other a decompositional group. In the compositional approach, as found in Papert et al (1979) and Papert (1980), students were first introduced to elements and were instructed to compose final products from the elements. In the decompositional approach, the stuents were presented with complete entities and were asked to analyze them by manipulating and modifying them.

Students' performance was measured using problems from the school's standard math curriculum, the Brookline Test of problem solving and a locally devised test of LOGO Knowledge in a pre and post test format and by examining the process of students' problems solving as captured in students' notebooks.

The performance of the class as a whole was compared from the pre test to the post test. On five of six Heath math problems, the students showed statistically significant improvement during the school year.

Students showed improvement on three of the four Brookline Test questions designed to test students' ability to solve problems in the LOGO domain. The results of the LOGO Knowledge Test indicate that the students' knowledge of LOGO increased from the beginning to the end of instruction.

The performance of the Compositional and Decompositional groups was also compared on the Brookline and LOGO Knowledge Tests. As expected, the compositional group performed better than the decompositional group on the LOGO Knowledge Test which assessed specific LOGO maneuvers which were a part of that group's explicit curriculum. Also as expected, the decompositional group showed more improvement than the compositional group on the Brookline Test which assessed students' application of problem solving strategies.

Students taught by the decompositional approach seemed to approach the programming problems differently than the students taught the compositional way. The decompositional group planned their products in advance while the compositional group treated their notebooks as record-keeping devices after they completed their work.

Based on these test results, we feel comfortable concluding that students who receive intensive and systematic instruction in problem solving and have the problem solving apparatus formulated for them explicitly can learn problem solving strategies and apply them to new problems that have a similar logical structure with different surface features. We are more cautious about our results concerning the utility of the compositional and decompositional approaches to teaching a programming language (LOGO) because our test data are not statistically significant.

Educational Implications

We are concerned about the resources that a teacher must marshal in order to accomplish the twin goals of computer mastery and academic learning.

Some suggestions for arranging the everyday classroom context to meet these goals based on the several strands of research that we have reported follow, as well as some warnings.

Teachers Teach, Machines Mediate

Computers extend rather than replace teaching done by teachers. Used properly, computers can extend the power of students to create, analyze, compare, examine and understand. Computer facilitated environments can promote creative thinking, extend systematic inquiry and problem-solving, and establish important skills for cooperative work, all skills that are vital for participation in our present and future society. Students need to learn more than facts, including how information is collected, stored and utilized to solve problems or create new understandings.

Educational Technology and Educational Policy

Educational innovations need to be driven by educational policy rather than by the availability of technology. When computers first made their way into schools, often under the arms of enterprising teachers (Sheingold et al, 1983), the problem was finding the appropriate educational software. The teachers in this and other studies (Cazden, Michaels, Watson-Gegeo, 1985; Heap, 1985) have taken a significant step beyond isolated computer use by demonstrating that it is possible to integrate computers into major curricular areas.

If computers are going to have a significant impact on schools, and not just be confined to exceptional teachers, then schools and school districts have to adopt a comprehensive plan for computer use. Simply saturating a school with the newest machines is not likely to result in innovative uses of technology.

The history of innovation in education (Sarason, 1982) has shown that attempts to institute change have failed unless the implications of the innovation for all aspects of the school system are taken into account. While the details of such a proposal are too complex for this space, two principles seem important: (1) change must be school wide and involve administrators and parents, not just teachers; (2) a consistent plan and program that integrates students of differing ability, curricular areas and grade levels is required.

Functional Learning Environments

Educational technology makes it possible to create learning situations in which students can be engaged in activities that they find interesting and exciting for their own reasons and which accomplish the educational goals of their teachers. Teachers established functional learning environments by relating the computer activities to other educational tasks the children were doing. The goal was to link computer work with other classroom work to establish a mutually supporting context in which similar skills could be applied. The teachers perceived this coordination of otherwise unrelated activities as potentially the greatest source of support for the children's computer work; after all, the students spent approximately eight hours a week on language arts and only 30 minutes a week on the computer.

Educational technology can create new avenues for social exchange and cooperative learning. Fears that computers will result in students working in isolation removed from all forms of human interaction can be dispelled by watching students in classrooms organized to promote peer interaction. Students solve problems collabatively, often with their teachers as partners. More, not less, social interaction results when technology is used to foster joint problem solving.

While it may be true that exceptional teachers can accomplish the goals associated with an integrated language arts curriculum without a computer, well-designed computer software can empower good teachers by providing them with guidelines for integrating a range of new tools with their teaching skills.

Networks of Social Support

Networks of social support are vital to make educational technology effective. There is a range of different ways this support can be provided but without it, innovative uses of computers are not likely to succeed.

Given our pedagogical goals, we selected software that had two important characteristics: One, it was user controlled; it could be modified by the teacher, translated into Spanish, or entirely new activities could be created in either language. Two, it changed the type and form of participation as the student became more skilled; if the student was new to the task, such as writing an essay, the software provided plenty of prompts to support and encourage writing; as the student improved the prompts diminished and the student did most of the work independently. For our purposes, this flexibility was very important. The bilingual teacher, for example, used the Spanish versions (some that she developed as she became more competent with the computer) and the interactional capabilities of the software to accomplish three essential goals: (1) to engage the whole class in the same computer activities, regardless of language proficiency, (2) to help LEP students apply their Spanish language and literacy skills readily to computer work, thus taking full advantage of the students' intellectual resources, (3) to help the students use their Spanish to work in English. Software was selected, modified or developed in the context of these goals.

People are a vital part of the network of social support for students who are learning academic tasks via microcomputer. Support provided by students or the participant observers was vital for all students, but especially for the LEP students who needed help with English, to decipher or perform assigned computer tasks. This additional support was enough to help the students do computer activities they otherwise could not do. As the students progressed in their computer work, the amount of help was reduced and the nature of the help changed. The social support was aimed at how to do a task, and more how to improve work done previously; or it provided guidance to LEP students about how to do in English what had previously been done only in Spanish.

Social support is as important to the teacher's development as it is to the student's development. Research is showing that adults as well as students seek out social experts rather than print material to help them acquire new technical skills (Bannon, 1985). Finding ways to provide this support is vital. Simply providing teachers with new computer equipment is clearly not sufficient. The extra-curricular help provided by the research team facilitated the teachers' rapid acquisition of the technical aspects of computer operations. In addition, it provided the teachers with valuable resources not available in the immediate environment (e. g., the use of participant observers to assist the children) and access to local experts who represented an indispensible crutch while teachers explored uncertain terrain.

This experience suggests that teacher training must be continual but be reduced as teachers gain mastery. Teachers need to acquire "threshold knowledge" about computers, including knowing how to select or modify the software the children will use and elementary trouble shooting, and this knowledge can be acquired while helping the students with their assignments. It is not necessary to postpone all worthwhile computer activities until the teacher is well-prepared. Just as multiple entry points were provided for the students, they must be provided for the computer-novice teachers. There is no one single way of becoming competent with computers.

Computer Literacy

As it is frequently taught, computer literacy is not a fruitful approach to computer use. It is not necessary to separate the teaching of machine operations from the teaching of machine uses; doing so is yet another example of a decontextualized approach to education, and has the potential to continue the existing educational stratification of students along social class lines. Students can learn about machine operations by using them to accomplish academic tasks. Integrating computers into the curriculum and using them as tools gives students a much richer sense of their power than spending time learning all the names and functions of the computer components separate from and before learning about computer uses.

Educational Tracking

Educational tracking can be reified by computer technology, i.e. when low income and low achieving students are given computerized drill and practice games while high achieving and high income students are exposed to simulations and tool use activities. This differential educational treatment is justified on the grounds that low achieving students need simplified tasks and massive doses of reinforcement, while high achieving students need advanced and challenging work. This rationale is uninformed and its concomitant stratification is unnecessary. When functional learning activities are created with dynamic support for low achieving students their scores on educational skills show improvement that is similar to that of students who are classified as gifted.

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APPENDIX 1

SELECTING PROMPTS AND RUBRICS

From Grubb (1981)

On the following pages are specific prompts you can use to have your students write stories (narrative writing), descriptions (descriptive writing), explanations (expository writing), and letters (practical writing). The prompts have been written for use with the different grade levels of SPECTRUM OF ENGLISH. You will also find prompts for persuasive writing for Grades 7 and 8, where this kind of writing is first introduced. With some word adjustment, you will probably be able to use prompts designed for one grade level with any group of students. If, for example, you are teaching from SPECTRUM OF ENGLISH Green (Grade 5), you will probably also be able to use slightly reworded prompts from Purple (Grade 4) and Gold (Grade 6) to evaluate your students' writing ability.

After each set of prompts, you will find a four-point and a six-point rubric, designed for use with the specific kind of writing elicited by the prompts. You can use these rubrics to score your students' compositions.

Prompts for Narrative Writing

Spectrum of English Yellow (Grade 3)

Imagine that you have found a magic wand. Think about how you found the magic wand. Think about how you will try to use the magic wand. Think about what will happen when you use the magic wand. Then write a story that tells about you and the magic wand.

Spectrum of English Purple (Grade 4)

Imagine you are taking a trip on a rocket. Think about what you will do when the rocket takes off. Think about what you will do during the trip. Think about what you will do when the rocket lands. Then write a story about your rocket trip.

Spectrum of English Green (Grade 5)

Imagine you and a friend are exploring another planet. Think about the most exciting adventure you and your friend would have there. Think about what would happen at the beginning, in the middle, and at the end of your adventure. Then write a story about the adventure you and your friend have.

Spectrum of English Gold (Grade 6)

Remember a time when you felt very frightened. Think about what happened to make you feel frightened. Think about what you did when you felt frightened. Think about how you finally stopped feeling frightened. Then write a story about the time when you felt frightened.

Spectrum of English Amber (Grade 7)

Imagine that while you are exploring a strange jungle, you become lost. Think about how you became lost. Think about what you do when you discover you are lost. Think about how you find your way back out of the jungle. Then write a story about being lost in the jungle.

Spectrum of English Emerald (Grade 8)

Imagine that you are trapped in an underground mine. Think about what you do when you discover that you are trapped. Think about the different methods you use to try to get out of the mine. Think about how you finally get out. Then write a story about being trapped in an underground mine.

Rubrics for Narrative Writing

Because it is used far less often than the four- or six-point rubrics, the nine-point rubric has not been included. If you need a nine-point rubric to assess the writing of a group of advanced students, expand the six-point rubric given here, using the nine-point rubric on pages 15-18 as a guide.

Four-Point Rubric

4 This is an excellent composition, with all or most of the following characteristics:

- ☐ a clear sequence of events which is an appropriate response to the prompt and which is introduced at the beginning of the composition
- ☐ clear development of the story, without irrelevant descriptions or explanations
- ☐ good organization, including a clear beginning, middle, and end
- ☐ fresh, vigorous word choice
- ☐ a variety of interesting details
- ☐ correct and appropriate structure in all or almost all sentences
- ☐ very few or no errors in the use of punctuation marks, capital letters, and spelling

3 This is a good composition, with all or most of the following characteristics:

- ☐ a sequence of events which is a good response to the prompt but which may not be entirely clear in every part of the composition
- ☐ good development of the story, which may, however, be marred by an irrelevant description or explanation
- ☐ good organization, which may, however, include undue emphasis on the beginning or the end of the story
- ☐ good word choice, which is, however, not particularly fresh or vivid
- ☐ sufficient details to maintain reader interest
- ☐ correct and appropriate structure in many or most sentences
- ☐ some errors in the use of punctuation marks, capital letters, and spelling

2 This is an adequate composition, with all or most of the following characteristics:

- ☐ a story line which is an adequate response to the prompt but which may be unclear in many parts of the composition
- ☐ adequate development of the story, which, however, probably includes one or more irrelevant descriptions or explanations
- ☐ organization which is not completely clear
- ☐ adequate word choice
- ☐ very few details which relate to the story
- ☐ incorrect or inappropriate structure in many sentences
- ☐ serious errors in the use of punctuation marks, capital letters, and spelling

1 This is an inadequate composition in which it is difficult to understand what the writer is trying to say. It may be very short or very long and rambling. The composition has all or most of the following characteristics:

- ☐ some indication of an attempt to respond to the prompt, although the story line is unclear
- ☐ story development which is unclear or completely lacking
- ☐ no understandable organization
- ☐ unspecific, immature word choice
- ☐ complete lack of details which relate to the story
- ☐ incorrect or inappropriate sentence structure throughout
- ☐ many serious errors in the use of punctuation marks, capital letters, and spelling

Six-Point Rubric

6 This is an excellent composition, with all or most of the following characteristics:

- ☐ a clear sequence of events, which is an appropriate

Rubrics for Descriptive Writing

Because it is used far less often than the four- or six-point rubrics, the nine-point rubric has not been included. If you need a nine-point rubric to assess the writing of a group of advanced students, expand the six-point rubric given here, using the nine-point rubric on pages 15–18 as a guide.

Four-Point Rubric

4 This is an excellent composition, with all or most of the following characteristics:

- ☐ a clear topic, which is an appropriate response to the prompt and which is introduced at the beginning of the description
- ☐ a clear development of the description, with few or no irrelevant stories or explanations
- ☐ good organization, including an introduction and a conclusion
- ☐ specific, vivid word choice
- ☐ sensory detail
- ☐ correct and appropriate sentence structure in most or all sentences
- ☐ few or no errors in the use of punctuation marks, capital letters, and spelling

3 This is a good composition, with all or most of the following characteristics:

- ☐ a topic which is a good response to the prompt but which may not be completely clear throughout the composition
- ☐ adequate development of the description, which may, however, be marred by an irrelevant story or explanation
- ☐ good organization, which may, however, lack a clear introduction or conclusion
- ☐ appropriate word choice, which is, however, not particularly vivid
- ☐ sufficient details to make the description clear

- ☐ correct and appropriate structure in most sentences
- ☐ some errors in the use of punctuation marks, capital letters, and spelling

2 This is an adequate composition, with all or most of the following characteristics:

- ☐ a topic which is an adequate response to the prompt but which may be unclear in many parts of the description
- ☐ minimal development of the description, which may include several irrelevant stories or explanations
- ☐ unclear organization
- ☐ unspecific or immature word choice
- ☐ few details which contribute to the description
- ☐ incorrect or inappropriate structure in many sentences
- ☐ many errors in the use of punctuation marks, capital letters, and spelling

1 This is an inadequate composition, in which it is difficult to understand what the writer is trying to say. The composition has all or most of the following characteristics:

- ☐ some indication of an attempt to respond to the prompt, although the topic of the description may be unclear
- ☐ development which is unclear or completely lacking
- ☐ no understandable organization
- ☐ unspecific, immature word choice
- ☐ complete lack of details which contribute to the description
- ☐ incorrect or inappropriate sentence structure throughout
- ☐ many serious errors in the use of punctuation marks, capital letters, and spelling

Six-Point Rubric

6 This is an excellent composition, with all or most of the following characteristics:

Appendix 2

Functional Computer Literacy Test

Introduction

Try to make the person feel as comfortable as possible. This is not a test, it is a discussion about the computer and what the person knows. They may learn some things that they did not know. Say something like:

> We want to know what you have learned about the computer this year. I am going to ask you some questions about the computer and how you use the computer. You will know the answers to some of these questions, but not all of them. You may learn some things about the computer. Everything you say is important to us because it will help us decide what to teach children about computers next year.

Hardware Questions

General instructions: point to the part of the computer indicated and ask the person to identify the part and tell what it is for. If the persons response is similar to one listed, mark that response. If it is different, either list it or if too long, index tape recording by T. For no response, mark O.

1. What is this? (Keyboard)
   What does it do? (lets you talk to the computer) (types letters)

2. What is this? (Monitor) (Screen) (TV)
   What does it do? (shows what is happening in the computer) (shows you what you are doing)

3. What is this? (Printer)
   What does it do? (type information on disk)

4. What is this? (Disk Drive)
   What does it do? (reads and writes information on the disk)

5. What is this? (Central Processing Unit)
   What does it do? (make the computer work)

6. What is this? (Memory Chip)
   What does it do? (store information)

7. What is this? (WA:SYSTEM Disk)
   What does it do? (starts the Writers Assistant) (reads information) (transfers information)

8. What are some of the things you have to do to be careful of discs?
   Probe: What are all the things you shouldn't do with discs?
   (food) (magnets) (grey area) (heat, cold) (bend)

9. What would you do if you put your disk in and turned on the computer and the screen was blank?

   If that didn't work is there anything else you can do?
   Repeat this question until the student says "no", number the responses
   (turn on the computer) (turn the contrast) (check if plugged to power) (check if plugged to computer) (ask a friend) (ask the teacher) (read the charts)

Working Knowledge

General Instructions: Turn off the computer and monitor. Show the person a WA:SYS and WA:TEXT disk. Ask the person to use the Writer's Assistant to type a sentence. Hand them a card with the sentence "Help, I am stuck in this computer." Tell them to save it in a file with their first name and to print one copy.

Indicate the sequence by numbering each step as the student does it.
Put a check mark if the student self corrects after an error.
Put a + if you needed to give some prompting.
Put a * if you had to tell the person how to do it.

Insert WA:SYS disk
Turn on computer
Turn on monitor
Selects (1) Writer's Assistant from menu
Inserts WA:Text disk
Enters By-line in response to "Hi, who are you" (optional)
Names file (in response to "what text do you want to work on?")
Uses (I)nsert command to enter text
N.B.: list here any cursor movement or use of control keys

Enters text
Closes with control-C
Leaves file with (Q)uit and (U)pdate
Removes WA:Text disk
Turns off machine (optional)

Writer's Assistant Commands

General Instructions: You will ask the student to demonstrate knowledge of a number of procedures in a step by step fashion. If a student cannot do part of the task, show the student how to do it. Then move to the next item. IT SHOULD NOT SOUND LIKE A LIST OF QUESTIONS. Say something like:

> OK, now we are going to look at another file on this disk and I will ask you some questions. If you don't know how to do something, I will show you how.

Find a file:

1. Give the person WA:SYS and WA:TEXT and ask them to see if they can find a news story written by John Drew on March 10. (NEWS-JD310). If not ask the person to find the file NEWS-JD310.

2. What would you do if the file was not on the disk? (look for another disk) (ask teacher)

3. Read the story. "What does it say?" "Do you want me to read it?"

Cursor Movement:

1. After student is in the file: What is that blinking light? (cursor) What does it do? (tells place)

2. Put the cursor on the word "baseball."
   (spacebar) (Control-I up/down key) (<-/-> key)

3. Do you know any other ways to move the cursor?

4. Can you make the cursor move word by word? (Control-I)

In, Drop, Xchange:

1. Insert the word "news" before the word "story" on line 3.
   Cursor movement: (spacebar) (CTRL-I) (up/down key) (<-/-> key)
   Command: (I)n (news) (CTRL-C)

2. Delete the word "night" on line 2.
   Cursor movement: (spacebar) (CTRL-I) (up/down key) (<-/-> key)
   Command: (D)rop (spacebar) (CTRL-I) (CTRL-C)

3. Exchange the word "father" for the word "mother"
   Cursor movement: (spacebar) (Control-I) (up/down key) (<-/-> key)
   Command: (D)rop (spacebar) (CTRL-I) (CTRL-C)
   (I)n (mother) (CTRL-C)
   (X)change (mother) (CTRL-C)

Aline and Word commands:

1. Do you know how to check the spelling of the word "two?"
   Cursor movement: (spacebar) (CTRL-I) (up/down key) (<-/-> key)
   Command: (W)ord

2. Can you center the title of this story?
   Cursor movement: (spacebar) (Control-I) (up/down key) (<-/-> key)
   Command: (A)line

Set the Environment:

1. Do you know if you can change the margins of your writing?

2. If yes, do you know how to do it?

Help command:

1. If you don't know how to use a certain command, what do you do?
   (read instructions) (ask another student) (use Help command)
   (ask teacher)

2. Do you know how to use the Help command?

Other commands:

1. Are there any other commands that you know that you can show me?

Quit commands:

1. Show me how you finish your work/leave the file. (CTRL-C) (Q)uit / (S)save
   (Q)uit / (U)pdate